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FOREWORD

All papers published in this number of the JOURNAL were read at the meeting held by the Association of Sugar Technologists of Porto Rico, at the Porto Rican Atheneum, at San Juan, P. R., on the 5th of July, 1925.

Three other papers were read at this meeting as follows:

1. The BH–10(12) and SC–12(4) Canes, by A. H. Rosenfeld.
2. Origin and Development of the Cane Sugar Industry in Porto Rico, by F. A. López Domínguez.
3. The Effect of the Root Rot Fungus, *Nematosporangium aphanidermatum* (Edson) Fitzpatrick, on the Germination and Growth of Sugar Cane Seedlings, by B. A. Bourne.

Of these, the first was published as No. 3 of Vol. IX of this JOURNAL, the second will be published greatly expanded in a coming number, and the third was withdrawn from publication by the author, who expressed the desire of doing a more exhaustive study of the subject before publishing on it.

The Association had Dr. W. A. Orton, Director of the Tropical Plant Research Foundation, of Washington, D. C., for its guest of honor on this occasion. Dr. Orton gave a very interesting talk upon problems in tropical agriculture and the future work of the Foundation.

F. A. LÓPEZ DOMÍNGUEZ,
Editor.

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AN EXPERIMENT ON DRAINAGE BY MEANS OF PUMPS IN THE CANE PLOTS "MANUEL MOLINA",[1] "FABRICA PAJAS 1ª.",[2] AND "FABRICA PAJAS 2ª.",[3] OF THE GIORGETTI COMPANY, IN THE MUNICIPALITY OF BARCELONETA, YEARS 1923–1925

By E. D. COLÓN, Agronomist and Field Manager, Compañía Giorgetti, and J. E. BERROCAL, Agricultural Chemist, Compañía Giorgetti

TOPOGRAPHY

The 43.50 acres to which this experiment refers lie at a little over one kilometer to the west of the town of Barceloneta and of the Plazuela Sugar Factory. They comprise three distinct fields which stretch from south to north in the order "Manuel Molina," "Fábrica Pajas 1ª.," and "Fábrica Pajas 2ª". The last two fields are named after the old "Pajas" mill built at the foot of the calcareous knoll which rises close by, the oldest factory known in the surroundings, the ruins of which may still be seen there. The east end of the knoll slopes and gradually merges into the lots "Manuel Molina" and "Fábrica Pajas 1ª.," for a short distance, forming the higher part of the 43.5 acres. The rest of the land is low, marshy, clearly muck-like at intervals, where the dark color of the wet soil becomes deeper. These characteristics become less pronounced in other neighboring fields toward the east, as the relatively higher levels of the valley of the Manatí river are approached; on the other hand, they are more noticeable as we travel in the opposite direction toward the muck soil and *blanquizales*[4] of the Tiburones marsh lands. So, then, these lots occupy an intermediate position representing a transition between the predominantly organic soils of the Tiburones basin and the predominantly mineral soils of the banks of the Manatí river. In the topographical chart drawn by the engineers J. D. Schuyler and J. M. Howells in the course of their studies for an irrigation project of the Plazuela holdings, these plots are

[1] Previous estimate, 18 acres: actual measurement in 1925, 17.5 acres.

[2] Sixteen acres.

[3] Ten acres.

[4] *"Blanquizales"* is the local name for patches of the marsh lands, which present an ash-like, whitish color on the surface.

traversed by the contour lines of 3, 4 and 5 feet of elevation above mean high tide. At present the land measures lower than this at various places if computed on the basis of the mean high tide. This might be explained by the fact that the tide records taken by these gentlemen were obtained during the months of March to September, thus leaving out of their observations, other months when very high tides occur. The calcareous strata of the neighboring hills affect visibly the chemical composition and the physical structure of the soil in inverse proportion to the depth at which they lie under the more recent deposits which constitute the soil. These strata are also responsible for the springs locally called *cáncaras*, common to this region, which come to the surface when the underground currents flowing between the strata of the tertiary calcareous rocks are for one cause or another interrupted in their course.

CONDITION OF THE LOTS

At the time when this experiment was planned, the lots referred to were covered by a net of water-furrows, quarter-drains, lateral and main-ditches common to the "grand-bank" system used in Porto Rico under these extreme conditions of soil moisture. This situation was further aggravated by the continuous use and cleaning of the ditches, which had made them larger than they were originally intended to be. The water level in this net of ditches oscillated with the rainfall and with the tide, which had full access to them, while the outflow was never enough to drain them completely. At the lowest places the water level rose to the surface of the soil when the tides coincided with heavy rains. Springs were more abundant in the fields nearer the Pajas knoll. Some of the *cáncaras* furnished mildly brackish water, often used for domestic purposes in times of drought. In their surroundings the muck-like condition of the soil was extraordinarily accentuated. When dry, a fine white efflorescence appeared on its surface. The almost constant saturation of the wet, soft subsoil, riddled often by large-size and small-size crab holes was apparent by inspection of the inside perimeter of the ditches.

The newly extracted clay subsoil was bluish white. The cane plants growing on this land were of yellowish foliage; they exhibited prematurely dried leaves, adhering close to the stalk, and showed a very poor stand. The Para grass languished at intervals, in the ten acres given up to pasture, overcrowded by vegetation more resistant to excessive moisture and salts, such as lichens, algae, eneas, (*Typha angustifolia*) arrocillo, (*Paspalum paniculatum*) salvia,

(*Salvia oficinalis*) and various reeds. It was impossible to mistake the fundamental cause of the low production, heavy annual replantings, and the relatively short duration of the plantings. There were also other contributing causes, almost as apparent as the fundamental cause; such as excessive distance between stools and between rows, and the salt concentration on the surface due to surface evaporation.

PREVIOUS PRODUCTION AND COSTS

The available data cover the year 1912 to 1923, when these fields were plowed and planted as *gran cultura,* as will be explained further on.

TABLE NO. I

YIELD IN HUNDREDWEIGHTS PER ACRE

	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average	Average Yield of the 3 lots
M. Molina	Fall Planting (Gran Cultura)	1st. Stubble	2nd. Stubble	.....	.....	Fall Planting (Gran Cultura)	1st. Stubble	2nd Stubble	3rd. Stubble	4th. Stubble	5th. Stubble	6th. Stubble		
18.00 acres	352	279	199	.....	.....	554	383	225	392	270	220	208	311 (8)	
Fábrica Pajas 1,	2nd. Stubble	3rd. Stubble	4th. Stubble	5th. Stubble	6th. Stubble	....	Fall Planting (Gran Cultura)	1st. Stubble	2nd. Stubble	3rd. Stubble	4th. Stubble	5th. Stubble		
16.00 acres	296	386	290	305	366 (4)	.....	500	225	391	270	200	298	321	316
Fábrica Pajas 2,	.....	.....	Spring Planting (Primavera)	1st. Stubble	2nd. Stubble	3rd. Stubble	4th. Stubble	.....	Fall Planting (Gran Cultura)	1st. Stubble	2nd. Stubble	.....		
10.00 acres	....		492	222	(4)	153	200	.....	400 (5)	264 (6)	(7)	....	280	

(1) The crops of both lots were counted together in this year, 1916.
(2) Five acres were cut for seed: no record of their yield is available.
(3) Ten acres were cut for seed: no record of their yield is available.
(4) The lot was surveyed in 1925, and the area was found to be 17.5 acres. This would bring up the yield to 320 *quintales*.

We have available only the cultivation costs for some of these years from 1912 to 1923. The costs of planting and cultivation for the *gran cultura* in "Manuel Molina" in 1917 reached, with the wages prevalent at that time, $4.69 per ton of cane; those for the *gran cultura* in "Fábrica Pajas 1ª." were, in 1918, $5.41 per ton; and those of *gran cultura* in "Fábrica Pajas 2ª." in 1920 (taking the mean cost of plant cane for that year, which tended to be lower, as there were no specific data for this field), $5.56.

Evidently this land required closer attention.

PREVIOUS STUDIES

Fortunately we had in our local literature the valuable work by Dr. Zerban, "The Marsh Lands of the North Coast of Porto Rico," Bulletin No. 4 of the Experiment Station of the Sugar Producers' Association of Porto Rico,[1] published in April 1913. The land to which this paper refers, is part of the "Hacienda Pajas" mentioned in his report, the only difference being that he operated a little farther to the northwest, in "Tablón 3," which at present is included in the field "Terrón," of the Giorgetti Company.

Dr. Zerban recognized drainage as the first necessity of the lands he was investigating.[2] He noticed the saline incrustations on the surface of the soil, and determined their percentage composition in Pajas[3] as follows:

Carbonic acid	0.00
Bicarbonic acid	7.08
Chlorine	50.36
Sulphuric acid	5.17
Calcium	3.90
Magnesium	1.37
Potassium	2.51
Sodium	29.59

He made determinations of the water-soluble salts in samples of soil and subsoil of the same locality and obtained the following results:[4]

	Bicarbonates	Chlorine	Sulphates
No. 10, Soil	.097%	.164%	.042%
No. 10, Subsoil	.090%	.212%	.047%

He also determined the salt concentration in the water of the

[1] Now the Insular Experiment Station.
[2] *Loc. cit.*, p. 40.
[3] *Loc. cit.*, p. 22.
[4] *Loc. cit.*, p. 25.

ditches near the places where he had taken his soil samples, and found:[1]

Parts per Million

	Total solids	Chlorine	Sulphates	Total acid radicals
No. 10	2,353.6	1,010	107.1	3,260

and he called attention to the influence of the springs of less salty water on the diminution of the salt concentration found in the water of the ditches which drained them.

With the help of Dr. Johnston, he correlated the vigor of the cane cultivated in the salty lands with the salt content of the soil, and concluded that there was a very close relation, stating that the cane did not present a normal aspect when the clorine in the soil exceeded 0.114 per cent equivalent to 0.198 per cent total acid radicals.[2] As there was no instance in which figures between 0.643 and 0.114 per cent chlorine were obtained, he could not determine the effect of these intermediate amounts on the growth of the cane. The mean between these figures would be 0.0785 per cent, which is not very far from that of 0.09 per cent and 0.06 per cent fixed by Maxwell and Eckart in Hawaii.

He attributed the poor appearance of the cane in Plot 3 of Pajas, to the high salt content of the soil, expressing the opinion that the bad effects of the salt would be even more pronounced, but for the attenuating effect of the high nitrogen and lime contents. The results of his analyses made according to the official methods (14) were as follows: (15)

Sample	Nitrogen	Phosphoric Acid	Lime	Potash
No. 10	0.38%	0.17%	1.51%	0.42%

In 1921 two samples of soil from Pajas were analysed Mr. F. A. López Domínguez, then Chief Chemist of the Insular Experiment Station. The samples were taken in the forty-three and a half acres under discussion, and the results were as follows:

Sample	No. 272	No. 276
Moisture	5.47	7.95
Volatile matter	18.70	22.21
Insoluble residue	56.01	54.98
Iron and Al oxides	20.22	19.60
Nitrogen	0.537	0.633
P_2O_5	0.105	0.180
K_2O	0.821	0.612
Lime	1.276	1.687

[1] *Loc. cit.*, pp. 26 and 27.
[2] *Loc. cit.*, p. 30.

In the Agricultural laboratory of the Giorgetti Company, samples of soil and subsoil from this same field were analyzed in 1922 by the analysts Mr. R. Fernández García and Mr. José E. Berrocal, using official methods (16) (Hydrochloric acid of specific gravity 1.115 as solvent), and the French method [1] in the determinations of alkaline salts. The results obtained were as follows:

Soil Samples

Reaction	Fábrica Pajas No. 2 By R. F. G.	Fábrica Pajas No. 1 By J. E. B.	Manuel Molina By R. F. G.
Moisture	7.715	7.092	7.442
Volatile matter	13.470 / 11.900 (18)	12.80 / 16.23 (18)	12.640
Humus	5.27 / 6.77 (18)	7.44	6.549
		0.2255	
Nitrogen	0.236	0.237 / 0.216	0.417 / 0.353 (18)
P_2O_5	0.213	0.293	0.318
K_2O	0.267	0.311	0.233
Carbonates	0.842	1.271	1.551
Bicarbonates	0.196	0.037	0.092
Chlorides	0.060	0.002	0.042
Sulphates	0.187	Traces	0.127

Subsoil Samples

Reaction	Alkaline	Alkaline	Alkaline
Moisture	9.265	7.850	7.462
Volatile matter	11.290	13.020 / 12.640 (18)	10.248
Humus	4.27 / 4.25 (18)	5.661	4.911
Nitrogen in humus		0.1044	
Nitrogen, total	0.064	0.135	0.230
P_2O_5	0.176	0.298	0.272
K_2O	0.267	0.311	0.233
Carbonates	1.077	1.758	1.304
Bicarbonates	0.253	0.028	0.057
Chlorides	0.081	0.002	0.055
Sulphates	0.269	Traces	0.105

These analyses were followed by determinations of the weight of the soil per cubic foot to the depth of 24 inches, obtaining:

Manuel Molina	69.00 pounds
Fábrica Pajas 1ª.	58.00 pounds
Fábrica Pajas 2ª.	60.20 pounds

The following calculations were made on the same samples:

Weight per Cubic Foot

	In the field on the recently drawn samples	In the laboratory, on the air-dried samples	In the laboratory, on soil dried at 100° C.
Fábrica Pajas 1ª.	100.2 97.9 (18)	62.8 59.2 (18)	58.0 55.2 (18)
Fábrica Pajas 2ª.	94.2	64.0	60.2
Manuel Molina	112.1	71.4	69.00
Averages	101.1	64.3	60.60

The samples were taken in July and August 1923 and in March and October 1924, so that the moisture retained by the soil and subsoil in the open air during these drier months would be approximately 36.8 pounds per each 101.1 pounds total weight, or 36.4 per cent.

Although obtained much later than the chemical data given above, we are giving below the results of analyses of samples from these fields made according to the Dyer method as modified by the chemists of the Hawaiian Sugar Producers' Experiment Station (20), using a 1 per cent citric acid solution.

		Manuel Molina	Fábrica Pajas 1ª.	Fábrica Pajas 2ª.
Soil	P_2O_5	0.0182	0.01252	0.01149
	K_2O	0.01499	0.01884	0.01875
	CaO	0.8595	1.2780	0.8570
	SiO_2	0.2258	0.1252	0.1847
Subsoil	P_2O_5	0.0134	0.00502	0.00926
	K_2O	0.0133	0.01656	0.01263
	CaO	0.7035	0.8991	1.509
	SiO_2	0.2938	0.0625(21)	0.1424

In a neighboring field, separated from the one under discussion by only a passage way (*callejón*), strong indications of the presence of ferrous salts in the subsoil were obtained, as well as unmistakable proofs of the presence of hydrogen sulphide. A silver coin was tarnished when placed in contact with the subsoil, in a hole recently made and the odor of hydrogen sulphide was distinguishable. Also, a light precipitate of ferrous ferricyanide, or Turnbull's blue, was obtained on a filter paper. The bluish white color of the fresh subsoil has been already mentioned. The water, leaking out of the walls of the ditches, leave on the subsoil tracks of a reddish-brown color, which stand out on the black color of the ground. All these were evidences of lack of ventilation.

COMMENTS ON THE FOREGOING CHEMICAL DATA

In the interpretation of results of chemical analyses of soils made by different analysts, as in the present case, experience shows that general results rather than any particular specific figure should be considered, as variations are bound to occur, even in one and the same sample, due to differences in the methods chosen, to details of manipulation, to the laboratory equipment, and to the personality of the analyst. In the data given by Dr. Zerban, sample number 10, taken from the ditches, seem to show rather high results in acid radicals as compared with the figure for total solids. The figure obtained for chlorides by Berrocal in Fábrica Pajas 1 would seem to be in error when compared with the others; and these latter show considerable variations amongst themselves. The variations introduced by the washing of the soils by rainfall, and by the salt concentrations brought about by evaporation, should, however, be borne in mind, as well as the fact that until 1920 no official methods were given for the determination of alcaline salts in soils, thus giving rise to the use of different methods by different chemists, according to the necessities and personal preferences of the analysts. The determinations made on extractions with HCl of specific gravity 1.115 by Dr. Zerban, by Mr. López Domínguez, and by Messrs. Fernández García and Berrocal differ considerably when compared figure for figure; but they agree as to the mediate fertility of those soils as shown by total nutritive ingredientes. With this point cleared, it is well to compare our analytical data with the standards used in other cases to judge the fertility of a soil.

For mixed soils in which clay predominates, Hilgard considers sufficient the following amounts, provided they contain a fair amount of lime, as in the present case: Nitrogen, 0.1 per cent; phosphoric acid, 0.1 per cent; potash, 0.45—0.85 per cent. Wolltman, in Tropical Africa, considers good soils those which, having 0.4 per cent lime, contain: Nitrogen, 0.12 per cent; phosphoric acid, 0.1 per cent; potash 0.2 per cent.

The foregoing standards for mineral nutrients refer to similar soil extractions with strong acids. According to them, our soils show up to be very rich.

As regards extractions with weak acids, such as citric, let us consider the following standards:

Harrison, in Demerara, fixed the following percentages as suf-

ficient for sugar-cane raising: Phosphoric acid, 0.007 per cent; potash, 0.008 per cent; lime, 0.006 per cent.

Dyer had already fixed in a general way, a content of 0.01 per cent of P_2O_5 or K_2O as the lowest limit, at which fertilizers should be applied.

Maxwell in Hawaii considered as good soil for cane, the low lands which contained: P_2O_5, 0.0023 per cent; K_2O, 0.019 per cent; lime, 0.067 per cent.

And McGeorge, lately in Hawaii, considers as fair soils for sugar cane those containing: P_2O_5, 0.004 per cent; K_2O, 0.03 per cent; lime, 0.314 per cent.

The tendency in these standards has been to increase rather than to decrease, from Dyer on, with the exception of the figure for phosphoric acid. According to the highest standards the soils under discussion would be deficient only in available potash, a point which will be verified in due time.

THE SITUATION

This could be now stated concretely: We had a plot which was not yielding properly, almost nothing in the 10-acre lot, and at a loss in the remaining 33½ acres.

The soil was not a normal mineral soil, as was shown by the muck soil still apparent in places, similar to that of the marshes to the west, the low weight per cubic foot, its high moisture-holding capacity, the low figures for "insoluble residue" and "silicates," and its high content of volatile matter, humus, and total nitrogen.

We have already seen that the potential fertility of these soils as shown by their content of phosphoric acid, potash, and lime, soluble in hydrochloric acid of specific gravity 1.115, was remarkable. And the deficiencies shown by their 1 per cent citric acid extraction, depended on the standards adopted for the interpretation of the figures obtained. These deficiencies, in any case would be shown only by the percentages for "silicates" and "potash," if the standards of McGeorge, in Hawaii, were used as basis of comparison. The high percentages of lime gave hopes of improvement, as soon as proper ventilation of the arable layers of the soil was obtained.

On the other hand, there were present dangerous amounts of salts, the concentration of which would increase with improved ventilation, unless the source of the salts, was cut off, by preventing the tides from getting into the plot, and the bad effects of evaporation were counteracted by washing accomplished by rainfall. There was,

besides, one other hope of compensation in the constant flow of almost fresh water derived from the springs above described, which might at any time be used to advantage for their amelioration.

As the ditches across the plot did not drain completely in many cases even in times of low tide and the water level came up flush with the soil surface in several places in times of high tides, it was decided to carry out a drainage experiment providing for the exclusion of the tide waters and pumping out the water from the springs, seepage, and rainfall, using the least possible number of ditches, in order to compensate for the extra expense required by the operation of the pump.

EXECUTION OF THE PLAN

As a preliminary test, four acres of the higher ground of the lot Manuel Molina were planted during dry weather, in the Spring of 1923. The old canals, too wide and deep already, were filled and new shallow ditches opened. The planting was done on banks of two rows each. The banks were made with implements on the furrow made when breaking up the old stubbles just harvested. The seed used was partly of Egyptian cane (P. O. J. 105) (4½ acres) and partly of Striped Cane (Striped Cheribon) (½ acre), and the planting was done toward the end of April. The yield was about 680 quintals (34 tons) per acre, harvested in May, 1924. The pump did not affect this field until the third week of November.

Encouraged by the good growth of this Spring planting, we began to prepare for *gran cultura* planting the remaining 38½ acres. In the Summer of 1923, all the old ditches were filled with dirt, ash, bagasse, and trash. Of the old ditches, only the one dividing the lot Manuel Molina in two plots (one of 5 acres, and the other of 12½ acres), was kept; so also the ditches around the perimeter of the 43½ acres, and a canal 3 to 4 feet deep in Fábrica Pajas 2ª, which, stretching from east to west along very low land, could be used to great advantage for collecting the water to be pumped.

Although after filling the ditches the land was rather soft, we were able to plow and cross-plow with bulls, using a moulboard plow Wiard No. 90; then the tooth-harrow and the disk harrow were used. Furrows five feet apart were then opened with a 16-inch double moulboard plow (*fullosa*), and on the one-row banks thus formed, furrows were made with a Wiard plow No. 62. This furrow was then cleaned with a small, adjustable double-moulboard plow of

German make, or with a celery hiller. The subsoil plow was then run along both, the planting furrow and the water furrow.

Then the ditching was done. We cut two main ditches, 4 feet wide, and from 2 to 4 feet deep, perpendicular to the collecting ditch, discharging in the latter. The ordinary quarter drains (*cruceros*) 3×2, were opened. Ditches were further made to drain the springs (*cáncaras*) of greatest flow.

The planting was then done, in a single continuous row. The variety planted was the Egyptian (P. O. J. 105), as it was desired to find out whether it would repeat in Plazuela the good results in tonnage and quality of juices reported from Aguadilla, although about one-forth acre of this cane had, however, been destroyed the year before, for its bad growth, in a different type of soil. The planting was finished in October 26, 1923.

Meanwhile, the installation of the pump was begun in the beginning of October, placing it at the outflow end of the collecting ditch. The ditches within the 43½ acres were isolated from any outside ditches. The pump was ready to work on the third week of November.

THE PUMP

We had available the daily precipitation for 1922, measured in the water-gage at Central Plazuela. The maximum in 24 hours had been, in that year, 3.62 inches on December 1, and 5.74 inches in the 48 hours of December 1 and 2.

The yearly precipitation in Barceloneta, according to the records of Weather Bureau at San Juan, P. R., varied during the years 1915 to 1922 from 45.04 inches to 74.13 inches, with an average annual fall of 59.93 inches, the most frequent and heaviest rains falling usually during the months of October to January.

In Holland, in the region around Lake Haarlem, with an annual precipitation of 27 to 40 inches, and drainage accomplished by open ditches and pumps, it has been necessary to pump up to three-eighths inch in 24 hours (21). In western England, with an annual precipitation of 50 inches, calculations for drainage are based on three-fourths of an inch in 24 hours. The records for June to October 1909 at the Willswood plantation, of the County of St. Charles in Louisiana, the precipitation and lands of which are similar to ours, and where the system of open ditches and pumps was also used for drainage, show that in two instances they had to pump 1.4 and 1.03 inches in 24 hours, after a rainfall of four inches; the ordinary pumping required is, however, of 0.7 to 0.8 inch in 24 hours. Refer-

ring to this case, Elliot considers as probably sufficient, a rate of 0.75 inch. Basing his calculations on a maximum precipitation of 24 inches, during the months of July and August (23), J. O. Wright estimated the rate of drainage for the Florida marshes, at 0.87 inch. Wiley determined the moisture-absorbing capacity of these soils, and fixed it at 128.75 per cent, as an average of nine samples.

None of these calculations, could, however, be properly applied to our case, not even the highest, obtained for places with precipitation similar to ours, for the following reason:

1. The small area of our field, 43½ acres, compared with the thousands of acres for which the run-off in the cases cited had been calculated.

2. The low elevation of the land on the mean sea level, which gives rise to a high water level, thus diminishing the depth of soil for rainfall absorption.

3. The springs, which overflowing into the plot, increase by additional amount of water they contribute, the rate of drainage that could be otherwise obtained.

More similar than any that we know of have seemed to us the conditions described by Jones, Schlick and Ramser in the basin of the rivers Black and Pearl, in Mississippi (23). Their measurements of the run-off to drain gave 1.00, 1.17, and even 3.48 inches in 24 hours; that is, about 60 per cent of the rainfall in 24 hours.

Accepting the run-off at 60 per cent of the precipitation, we would have for the 24 hours, a maximum amount of water to pump, in 1922, of $3.62 \times 0.60 = 2.172$ inches, not counting the water contributed by springs and seepage, which vary with differences in level of the water table.

That we are not far from the truth in adopting 60 per cent as the proportion of the rainfall to drain, is shown by the following calculations, based on the water-holding capacity of the soil under consideration:

3.62 inches of rainfall in 24 hours over 44 acres (25)	= 36,067,034.08 pounds (1)
Average moisture contained by the soil in months of scanty rainfall, 36.4 per cent on the weight of the soil *in situ*.	
Ditto, to complete saturation, according to Crawley, 44 per cent.	
Surplus capacity for use in times of rainfall, 7.6 per cent, which on 43½ acres	= 14,400,936.00 pounds (2)
Difference that must be drained in 24 hours	= 21,666,098.08 pounds (3)
Ratio (3) to (1)	= 60%

To drain this amount of water in 24 hours, we would have to pump at the rate of 1,805 gallons per minute.

Bearing in mind the unknown amount of water that might be supplied by the spring and seepage, it was decided to install a pump of greater capacity, (2,100–5,000 gallons per minute) operated by an oil motor, type Y, Semi-Diesel, of 15 H. P. According to the manufacturers, such a pump should be capable, under a head not to exceed 10 feet, of draining 4 inches of rainfall from 61 acres in 36 hours. As a matter of fact, there have been instances when we have had to pump consecutively during one day and night and the following day, in order to remove the water fallen. In times of drouth and no trouble in the motor we have pumped from one-half to 1 hour daily, to remove the water from springs and seepage.

To test roughly the efficiency of the installation the following calculations were made, based on data obtained on May 29th, when 4.14 inches of rain fell in the course of a few hours, filling all the ditches, and flooding the lower parts of the plot.

The pump operated normally, and the water was removed in 32½ hours (1,950 minutes).

$$\frac{4.14 \text{ inches} \times 43.5 \text{ acres} \times 1{,}000{,}000}{12 \times 3.0689} = 4{,}890{,}188 \text{ gallons.}$$

$$\frac{4{,}890{,}188}{1950} = 2{,}507 \text{ gallons per minute.}$$

$$60\ \% \text{ of } 2{,}507 = 1{,}504.2 \text{ gallons.}$$

The efficiency of the plant then resulted too low, estimating run-off at 60% of the rainfall-probably too low for this particular case.

THE PLANTATION

After replanting and fertilizing, the cane grew without interruption and exhuberantly, an unfamiliar occurrence in these fields, the planting of a part of which at least had always been considered a waste ot time and money.

Several analyses were made of the water on samples taken at the intake of the pump, and from the outflow canal outside the lot, to compare their chlorine content. The results were unexpected. The water from the inside ditch showed a higher percentage of chlorine than that of the outside canal, as may be seen from the following figures.

Date	Number of determinations average	Parts of chlorine per million average	
		Inside	Outside
From December 20, 1923, to February 19, 1925	35	696.54	549.28

The last two weeks during which samples of water were analyzed (February 8 and 19, 1925) a mean concentration of 675 parts of chlorine per million was found, as compared with 769 parts per million found for the first two weeks (December 20 and 28, 1924). This seemed to indicate a slow washing by the fresh rainfall water.

In March, 1924, there was a severe drought. The plantation was beginning to show its effects. As a test, we decided to irrigate five acres of Fábrica Pajas 2ª. with same water that was pumped from the plot. This was done, conveying the water from the discharge of the pump to the land by means of wooden conduits. The plantation improved visibly by the weekly irrigations given on the 21st and 28th of March and 4th of April. Then the rainfall made it unnecessary to continue the test.

In August, 1924, it was easy to foresee that the yield would not be less than 800 quintals per acre.

The harvesting began on January 5th, 1925, and by February 18th the 38½ acres of plant cane and the 5 acres of first ratoons had all been cut and hauled to Central Plazuela. The results were as follows:

Gran Cultura 14 months	Quintals Yielded	
	Total	Per acre
Fábrica Pajas 1.	16,880.60	1,055.00
Fábrica Pajas 2.	8,984.80	898.48
Manuel Molina	11,849.70	971.97
Average	37,715.10	979.61

The ratoon cane in the 5 acres flowered at 10 months. It gave 2,421.90 quintals, or at the rate of 484.38 quintals per acre.

The stubble, in general, has required very little replanting, and at the time of writing (May 1925) it is growing very well and promises to give a fair crop for 1926, with reasonable expenses for cultivation.

The results obtained have surpassed our greatest hopes. It is possible that they may be duplicated in many parts of Porto Rico.

Costs

1. Installation of pump and motor, with shed, full expense	$3,546.21	
Amortization in five years, annual charge		$709.24
2. Materials for repairs and for pumping (petroleum, gasoline, oil)		461.46
3. Wages, pumping and repairs		276.57
4. Cost, planting and cultivation, 38½ acres plant cane and 5 acres first stubble		4,731.90
Total cost		$6,179.17
5. Tons of cane produced		2,006.85
6. Cost per ton of cane, counting amortization		$3.07
7. Cost per ton of cane, not counting amortization		$2.72

WHAT SUGAR-CANE VARIETY TO PLANT

By R. A. VEVE, in charge of Experiment Station, Fajardo Sugar Growers.

I have taken as a subject for this paper to be read before you, "What Variety to Plant". I have taken this subject because this is an every-day question made by the cane growers, and no doubt a very important one. Offhand, it seems very easy to answer this question, especially if the person that is questioned has had any success with a specific variety of cane; he will immediately advise his friends to plant nothing but that variety that has done so well with him.

To my mind, and no doubt to the mind of most of you present, this is a very hard and delicate question to answer since it may involve great financial losses. Whenever this question is put up to me, my answer is that it is up to every cane grower to decide what variety is best adapted to his soil and special conditions prevailing in that region. Naturally I don't mean by this, that if my neighbor has exactly the same kind of soil and conditions and I have had success with a certain variety of cane that I would hesitate to recommend it to him, but I do mean that to-day in Porto Rico, and this is a very common practice, because a variety does well in one section most of the growers think that it should give similar results in the whole Island. I can safely say that at present there have been great losses experienced by cane growers as well as factories due to the little or no importance given to the adaptation of varieties to the different localities. Reading the JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF PORTO RICO, Vol. 8 No. 3, for the month of July 1924, in the article "Some Java P.O.J. Seedlings in Tucumán and Porto Rico", I find a paragraph by Mr. A. H. Rosenfeld whose clear mind has sized up this question of how varieties are planted. His paragraph I quote as follows:

"In the case of varieties of sugar cane, size and appearance, yes, even a characteristic color or mode of growth may exert more influence than their actual productivity or resistance to disease and it appears to the author that we could find no better illustration of this fact than the case of D–433, the well-known "Ceniza" cane, which has proven so valuable under the peculiar conditions of Central Fajardo, in Porto Rico. Careful experimentation and years of experience at this progressive central have demonstrated beyond the shadow of a doubt the value of this cane—normally a variety of good tonnage but indifferent sugar content—under the conditions of most of their properties, but this demonstration

under limited conditions does not justify the wide distribution of D–433 under materially distinct environment of soil and climate. No one will deny, we think, that the good size and ease of identification of this variety, as well as the notoriety it has received from its good record at Fajardo, have been more potent factors in its wide distribution than the results of carefully conducted field trials under the actual conditions of the many other sections into which it has of late years been extended.''

Just as a matter of illustration I am going to give some more details of this specific case.

The variety used in Fajardo in a plantation scale (when I say in Fajardo I mean administration cane as well as *colono's*), is the D–433: I know very well from experience as well as records obtained from other factories and experimental stations that this variety has been a great failure in most parts of the Island, but I do know that this cane has been the savior of the sugar business in our district.

In evidence of the above statement let me give you acreage and tonnage of this variety for the last five crops and the average tonnage obtained by the Fajardo Sugar Growers' plantation so that you have a clear idea of what the introduction of the variety D–433 meant for the sugar business in our region. The yearly acreage not reported as D–433 includes at least one thousand acres of BH 10–12, SC 12–4, Y.C., D–109, F. C. Seedlings and other varieties exclusive of Cristalina and Rayada.

Crop Year	Variety	Acreage	Tons Cane per Cda.	Brix	Purity	Yield	T. Sugar Per Cda.
1921	All included	9,601.7	16.75	18.25	82.90	10.70	1.79
	D 433 exclusively	453 3	26,37		82.70	10 30	2,72
1922	All included	8.615.02	20 74	18.28	84.15	10 95	2,27
	D 433 exclusively	1.517.81	33.92	18.20	82.90	10.40	3.51
1923	All included	7,773.29	19.94	18.64	84.54	11.28	2,25
	D 433 exclusively	2,495.06	26,42	18.90	84.60	11.30	2,97
1924	All included	8.045.16	26.86	17 71	82.24	10.25	2.75
	D 433 exclusively	4,095.90	32.52	17.90	82 60	10.40	3.35
1925	All included	7.485.60	31.74	17.94	82.27	10.40	3.30
	D 433 exclusively	4.245 97	35.61	18.24	82.81	10.78	3.84

NOTES:

Figures for crop 1925 only include cane harvested up to June 25, 1925.

In crops 1921, 1922 and 1923 no B. H. 10–12 or S. C. 12–4 were harvested, and very little for crops 1924 and 1925.

Now I will give you some data in this same variety, D–433, which

have been obtained from Central Carmen, Vega Alta, and which goes to prove that a variety that behaves well in a place does not necessarily give equal results when tried elsewhere.

Kind of cane	Acreage	Tons Cane per Cda	Brix	Purity	Yield	Tons Sugar per Cda.
G. C.	96.67	28.34	13.71	76.5	7.10	2.01
G. C.	9.10	43.74	15.66	77.6	8.35	3.65
Primavera	22.69	38.66	15.44	78.4	8.14	3.15

You will naturally ask the question of why these great differences. The following is my explanation:

The soils of Vega Alta where this cane was planted are of a sandy structure while the ones of Fajardo are heavy clay formations. To my best understanding this is the main reason, as it has been our experience that D–433 whenever planted in the sandy soils of Fajardo has given as poor or poorer results than the ones obtained in Vega Alta. I am only mentioning the soil factor, but there are others such as climatic conditions, cultivation, etc., which also affect the adaptability of a variety; for instance, we are propagating today a great deal of our seedling F. C. 306, which is a high-tonnage and rich sugar cane, in our plantations, yet we had to discard it from one of our estates situated in a high altitude and where the precipitation and atmospheric humidity is very great, because it is extremely susceptible to the leaf eye-spot disease.

I have taken D–433 as an example, because it is the cane with which we have experimented most, but I could have used B. H. 10–12, S. C. 12–4 or any of the great number of varieties we have in Porto Rico for the same purpose. I have seen results obtained from S. C. 12–4 in Mercedita, Ponce, and personally examined the cane fields, and nothing better could be expected. In Humacao this variety also does excellently, yet in Fajardo our experience has been that of a very high sucrose cane but low tonnage per acre. We had a technologist from the Federal Experimental Station visiting our fields some time ago and he refused to believe that this was the same S. C. 12–4 they had in Mayagüez. I am only mentioning this to impress upon you the behavior of varieties in different localities.

I also want to make clear to you that even with the good results that we have obtained with the D–433 we do not expect to keep it in our fields for a lifetime. There may be today hundreds of other varieties that will do even better than D–433 and this is the kind of investigations that every cane grower should make when possible.

At present great hopes are placed in B.H.10–12 to replace D–433 as a *gran-cultura* cane (long growth), as it will give equal tonnage and higher sucrose content, but in *Primavera* planting and ratoons running between eleven and twelve months old, so far D–433 is showing some superiority.

In concluding we would recommend to all cane growers not to accept any offhand advice as to the variety he should plant unless the special variety recommended to him has been successfully and thoroughly tried out in his section.

The ideal of every cane grower is to find a high tonnage variety with an equally high sucrose content. I firmly believe that this could be attained if all the centrals of the Island that have means to do it should run experimental stations. These stations should carry out the expensive work of determining which is the variety best suited to their region and recommend it to the planters.

RELATIONSHIP OF CANE VARIETIES TO DISEASES

MELVILLE T. COOK, Plant Pathologist, Insular Experiment Station,
Río Piedras, P. R.

It is very generally recognized that some varieties of plants are much more resistant to certain diseases than others. This is very readily observed in both wild and cultivated plants. Even the most casual observer cannot fail to note that diseases do not spread uniformly through a growth of wild plants or over a field of cultivated plants. This is because some plants are more resistant than others. Susceptibility to disease may account for the complete extermination of some species and varieties of wild plants in the past. It certainly does account for the abandonment of some varieties of cultivated plants within very recent time.

The fact that some plants are more resistant to certain diseases than others has been utilized by the growers of plants for many years; in fact, this practice is so old that it is impossible to tell just when man first began to select plants that were resistant to disease. Within recent years, many diseases of plants have been brought under control by the selection of resistant strains and varieties and this method is now very generally recognized as one of the most important in our fight against the many diseases of our crops.

The sugar-cane growers of Porto Rico have long ago learned that the selection of resistant varieties is a most important method of fighting some of our enemies. The growing of the recognized varieties of twenty-five years ago, have been greatly reduced, because of their susceptibility to mosaic and new and more resistant varieties have come into use. A few years ago, the gummosis disease became a threatening factor in Porto Rico, but is now of comparatively little importance because our growers have learned that it can be eliminated by the growing of resistant varieties (See Matz, J., Gumming Disease of Sugar Cane", Journal of the Department of Agriculture, 6:5–21, July, 1922).

But our growers have also learned that resistance to dissease is only one of many variations of sugar cane. Varieties differ greatly in character of growth, amount of tonnage, fiber, sucrose, and other factors which are quite important. This is true, not only in Porto Rico, but also in other cane-growing regions of the world

and is probably the most important line on which our specialists are working for the advancement of the sugar-cane industry. The result is that the development of sugar-cane varieties is receiving more attention at present than at any other time in the history of the sugar industry and new varieties are being developed in great numbers.

With these facts before us, let us inquire a little more closely into the question of varieties and their relation to the future of the cane-growing industry. It has been long recognized that all plants are subject to variation; in fact, it is often said that no two plants are exactly alike. The resemblances may be so close that it is practically impossible to detect the difference, but the differences are there; and it is this tendency to vary that has given rise to the enormous number of varieties of cultivated plants. In fact, some of the greatest advances in agriculture have been made by workers who were able to recognize and preserve valuable varieties. This has been practiced for centuries more or less blindly by men who did not understand natural laws of variation which have been demonstrated in recent years.

Varieties may arise in several ways, but the three most common are:

1. A gradual variation in which it is necessary to select the most desirable plants through a number of generations. In this manner the desired plant may eventually be secured.

2. Very pronounced and stable variations may appear within a single generation. These variations are known as "Mutants" and may be good or bad. These variations must be studied by well trained workers and tested from many angles in order to determine their relative values.

3. The careful breeding of plants by cross-pollination and production of seedling from which selections must be made by competent judges. This has become a very general practice in many of the cane-growing regions of the world and has given rise to a large number of seedlings.

The selection of desirable varieties by one who understands what is wanted may at first appear to be a simple process, but plants possess enormous numbers of characters, some desirable, some undesirable, some prominent and easily recognized, others hidden and evasive. Furthermore, this enormous number of characters are subject to an endless number of groupings. It will be readily seen that these factors give rise to a great number of complications. But this is not all; a variety may behave quite differently in different

parts of the world or under different environmental conditions in contiguous territory.

The growing of new varieties has now reached proportions unthought of a quarter of a century ago and new varieties come and go with such rapidity and in such great numbers as to be almost bewildering.

It is the purpose of this paper to consider this subject of new varieties from one angle only—that of plant disease. Of course, a new variety that does not grow well, give good tonnage, good sucrose content, and possess other qualities that are desirables from the standpoint of sugar production, will be eliminated from consideration.

Many of the breeders of sugar cane are thinking more of tonnage and sucrose content than of other factors. But a cane that possesses these good qualities may also possess bad qualities such as susceptibility to some of our well-known diseases. Even a seedling from parents that are resistant to a disease may prove to be very susceptible to that same disease.

But there are two other factors which must not be overlooked. (1) An insignificant disease may find a new variety so favorable for its growth, that it will suddenly become a disease of major importance. (2) A disease of grass may find the new variety of cane to its liking and develop into a serious problem.

Let us take a few examples:

(1) Cane mosaic must have existed previous to the first report from Java in 1890. It is easy to say that it spread from Java throughout the greater part of the cane-growing world, but that it is not easily proven. However, no one who has studied the subject will fail to understand that it has a very definite relationship to other varieties. This is well know to our Porto Rican growers and the use of resistant varieties has been and probably will continue to be one of the most important methods of fighting this disease.

(2) The vascular disease or dry top rot (*Plasmodiophora vascularum*) which has been found only in Porto Rico. It is especially severe on D–109, when grown in low, rather wet land, but it also attacks several other varieties. Where did it come from? How long has if been an enemy to cane? It appears that the best method of combating this disease may be in the use of a resistant variety.

(3) The "eye spot"[1] is a very old and very widely distributed disease. It may have been in Porto Rico for centuries, but was

[1] Sometimes called the Manatí disease.

never considered an important factor until 1923. It is now looked upon as one of our most important diseases. It has no doubt suddenly become serious because of the coming of new varieties of cane which are susceptible. In Hawaii this disease is most severe on H–109, but in Porto Rico we have a number of varieties that are more susceptible such as D–109 and FC–306. This is one of our important problems and it appears at this time that the selection of varieties and place of planting will be the two most important factors in controlling this disease.

(4) Gummosis was first found in Porto Rico in 1920, although it was reported from Australia a quarter of a century before that date. It may not be possible to determine where it originally came from or how long it had been in Porto Rico previous to its discovery, but it has been demonstrated that it can be controlled by the use of resistant varieties.

These four important diseases (mosaic, dry top rot, eye-spot, and gummosis) are well known to this audience. They have all, with the exception of the "eye spot", been discovered in Porto Rico within the past ten years, although they may have been here a much longer time. In fact, the "eye spot" may have been here almost from the beginning of the sugar industry. Their history in Porto Rico is a most excellent proof of the importance of the selection of resistant varieties in the growing of sugar cane.

The records show a dozen or more minor diseases of sugar cane in Porto Rico, any one of which may become of importance at any time provided it finds a suitable host variety. Minor diseases which suddenly become important are frequently looked upon as "new" by those who are unfamiliar with plant diseases, but if we could only learn their full history, we would find that some of them were formerly minor diseases while others may have come from related uncultivated plants.

But the selection of varieties of high tonnage, high sucrose content, and high resistance to disease must bring other factors into consideration, the most important of which are relationship to soil and climate. This is well illustrated in the case of the "eye spot" which is most severe in regions and during periods of high rainfall. Although this disease was severe in 1923, it did not attract much attention in 1924, but was very abundant in 1925. It is now looked upon by many of our growers as a disease of major importance and is one of our major problems at the Insular Experiment Station.

Therefore, it appears that the development of new varieties will

very probably bring into prominence certain diseases which are of minor importance at this time and that our problems will become more and more complex. However, this must not be interpreted as an argument against the development of new varieties. The development of new varieties is the key to progress in the sugar industry in Porto Rico and in other parts of the world. But we must recognize that our troubles are not ended with the mastery of mosaic.

New and more complex problems will arise from time to time with the finding of varieties of high tonnage and high sugar content. Every advance in the development of improved varieties will introduce new problems of diseases and some of these problems may be far more complex than those that are before us.

STEAM CONSUMPTION IN AN ELECTRIFIED SUGAR MILL

By JOSÉ R. CARRERAS, B. S., Chief Engineer, Juncos Central Co.

This paper is a brief abstract of a complete study made on the steam consumption of a sugar factory of this Island, with a quadruple effect evaporative installation, and on the expected steam consumption after the addition of a pre-evaporator which would supply also vapors to the juice heaters.

The scheme of adding a pre-evaporator to a quadruple effect forming a quintuple, and at the same time, supplying vapors at double effect to the juice heaters, is not new, as most of you may know. Noel Deerr in "Sugar" and Hausbrand in "Evaporating, Condensing, and Cooling Apparatus", treat that and similar schemes fully, and actual installations may be found in Cuba, Hawaii and other countries. So far as I know, though, this system has never been worked before in Porto Rico.

Before going into the discussion of the steam requirements, in the actual and in the system in project, a brief description of the factory apparatus and process is necessary.

Actually, the factory is almost wholly electrified. It has one 750 KW. Westinghouse Reaction type steam turbine and one 500 KW. Westinghouse Impulse type turbine. One Corliss engine of 120 HP. and one Corliss engine of 450 HP. drive most of the mill, and 100 HP. in small steam pumps are scattered in various works in the factory.

The juice is passed through three juice heaters, 1,250 square feet H. S. and heated to 212 degrees Fahr. After being clarified, it enters the quadruple effect at an average temperature of 180 degrees Fahr., and leaves as syrup of 27 degrees Beaume. Strikes of "Puras" and "first", massecuites are done in a calandria pan; "second", "third" and some "first" are done in two-coil pans.

The juice heaters and quadruple effect work with exhaust steam and the addition of live steam to mantain 6 lbs. ga. back pressure at the evaporator, or 11 lbs. ga. at the engines.

The calandria pan works with exhaust steam exclusively. The coil pans work mainly with live steam.

With the system in project, the juice heaters will work with vapors from the pre-evaporator; the pre-evaporator will work with the exhaust steam pressure same as previously; the calandria pan with exhaust exclusively, and the coil pans with live steam mainly, or if able, with exhaust steam exclusively. A new juice heater, 1,000 square feet H. S. will be installed also, for reheating the juice after clarification, and will work with vapors from the pre-evaporator.

Now, a word before submitting the results obtained. It would be foolish to claim exactness in the figures to be submitted. They represent the results from average conditions at the usual heavy rate of grinding and for maximum normal extraction of 83 per cent and 35 per cent dilution on cane. The calculations have been made mainly to show the relative proportions among the steam requirements of the different apparatus in the old and in the system in project. Please remember, therefore, that the tabulation of results given below must be considered as fairly approximate to the steam consumption of the apparatus.

TABULATION OF RESULTS FOR THE 750 KW. TURBINE UNIT IN SERVICE

	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	Live or exhaust steam consumption in lbs. of steam per lb. juice per hour.	B. T. U. consumption per lb. juice per hour.	B. T. U. consumption per lb juice per hour	B. T. U. consumption in per Cent of total B. T. U. consumption.	B. T. U. consumption in per Cent of total B. T. U. consumption.
	Quadruple	Quintuple	Quadruple	Quintuple	Quadruple	Quintuple
POWER:						
Turbine 750 K. W. unit.	0.2491	0.2491	25.24	25.24	4.97	6.01
Corliss Engines	0.1054	0.1054	10.19	10.19	2.01	2.43
Steam Engines	0.0616	0.0616	1.57	1.57	0.31	0.37
EVAPORATION & BOILING:						
Heating of juice	0.1370	.....	118.80	.....	23.38	.....
Reheating of juice	0.0464	0.0052	40.14	4.50	7.88	1.07
Evaporation	0.2220	0.3135	192.44	270.47	37.92	64.51
Boiling in Cal. Pan	0.0931	0.0809	80.66	70.04	15.85	16.71
Boiling in Coil Pans	0.0068	0.0068	6.54	6.54	1.29	1.56
Evaporation of added water in pans	0.0212	0.0212	20.42	20.42	4.02	4.87
LOSSES:						
Steam pipe losses	0.0020	0.0020	2.00	2.00	0.39	0.47
Condensation losses	0.0105	0.0087	10.05	8.40	1.98	2.00
			508.05	419.37	100.00	100.00

Comparative Heat Balance in Pounds Steam per Pound Juice per Hour, 750 KW. Turbine Unit in Service

WITHOUT PRE-EVAPORATOR SYSTEM:			
Exhaust produced by—			
Turbine	0.2491		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.4161	
Exhaust required—			
First heating	0.1370		
Reheating	0.0464		
Evaporation	0.2230		
Boiling in calandria	0.0931		
			0.4995
Deficit in exhaust steam		0.0834	
		0.4995	0.4995
Deficit in exhaust steam			0.0834
Deficit in live steam equivalent			0.0746
USING PRE-EVAPORATOR SYSTEM:			
Exhaust produced by—			
Turbine	0.2491		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.4161	
Exhaust required—			
First heating	0.0000		
Reheating	0.3135		
Evaporation	0.0052		
Boiling in calandria	0.0809		
			0.3996
Excess in exhaust steam			0.0165
		0.4161	0.4161
Excess in exhaust steam		0.0165	

TABULATION OF RESULTS FOR THE 500 KW. TURBINE UNIT IN SERVICE

	Live of exhaust steam consumption in lbs. of steam per lb. juice per hour.	Live of exhaust steam consumption in lbs. of steam per lb. juice per hour.	B. T. U. consumption per lb. juice per hour.	B. T. U. consumption per lb. juice per hour	B. T. U. consumption in per Cent of total B. T. U. consumption.	B. T. U. consumption in per Cent of total B. T. U. consumption.
	Quadruple	Quintuple	Quadruple	Quintuple	Quadruple	Quintuple
POWER:						
Turbine 500 K. W	0.1849	0.1849	18.74	18.74	3.73	4.56
Corliss Engines	0.1054	0.1054	10.19	10.19	0.03	2.46
Steam Engines	0.0616	0.0616	1.57	1.57	0.31	0.37
EVAPORATION & BOILING:						
Heating of juice	0.1370		118.80		23.67	
Reheating of juice	0.0464	0.0052	40.14	4.50	8.01	1.08
Evaporation	0.2230	0.3135	192.44	270.47	38.87	65.53
Boiling in Cal Pan	0.0931	0.0809	80.66	70.04	16.06	16.96
Boiling in Coil Pan	0.0068	0.0068	6.54	6.54	1.30	1.58
Preparation of added water in Pan	0.0212	0.0212	20.42	20.42	4.07	4.95
LOSSES:						
Steam pipe Losses	0.0020	0.0020	2.00	2.00	0.40	0.48
Condensation Losses	0.0105	0.0087	19.05	8.40	2.00	2.03
			501.55	412.87	100.00	100.00

Comparative Heat Balance in Pounds Steam per Pound Juice per Hour, 500 KW. Turbine Unit in Service

WITHOUT PRE-EVAPORATOR SYSTEM:

Exhaust produced by—		
Turbine	0.1849	
Corliss engines	0.1054	
Steam engines	0.0616	
		0.3519
Exhaust required—		
First heating	0.1370	
Reheating	0.0464	
Evaporation	0.2230	
Boiling in calandria	0.0931	
		0.4995
Deficit in exhaust steam		0.1476
		0.4995 0.4995
Deficit in exhaust steam		0.1476
Deficit in live steam equivalent		0.1321

USING PRE-EVAPORATOR SYSTEM:

Exhaust produced by—			
Turbine	0.1849		
Corliss engines	0.1054		
Steam engines	0.0616		
		0.3519	
Exhaust required—			
First heating	0.0000		
Reheating	0.0052		
Evaporation	0.3135		
Boiling in calandria	0.0809		
			0.3996
Deficit in exhaust steam		0.0477	
		0.3996	0.3996
Deficit in exhaust steam			0.0477

Now, let us discuss the figures obtained for the 750 KW. turbine unit, which is our most convenient condition in the actual installation.

Without the pre-evaporator, 0.0746 pound of live steam per pound juice per hour must be added to the exhaust for the heating requirements. If we could save this live steam, the economy for a 24-hour day would amount to—

$162{,}250 \times 0.0746 \times 24 \div 7.37 = 39{,}415$ pounds of coal, or 17.6 metric tons per day.

Coal is considered as having 11,850 B.T.U.

Efficiency of boilers as 60 per cent.

Equivalent Evaporation $= 11{,}850 \times .6 \div 963.61 = 7.37$.

If a $10 price per metric ton of coal is considered, and if it were posible to maintain the 1,500 tons per day rate of grinding during 125 days of the season, the saving would amount to—

$17.6 \times 10 \times 125 =$ $22,000 for the year.

With the installation of the pre-evaporator under the scheme explained, it is seen from the tabulations, that working with the 750 KW. turbine unit, there will not be the necessity to add any live steam to the exhaust; to the contrary, there will be an excess of exhaust steam of 0.0165 pound per pound juice per hour, which represents about $0.0165 \times 100 \div 0.4161 = 4$ per cent of the total exhaust steam produced. This excess may be employed to substitute live steam in the coil pans, and thus its loss be avoided.

For the 500 KW. unit, the difference between the deficit of exhaust steam in both cases is $0.1476 - 0.0477 = 0.0099$ pound exhaust per pound juice, or 0.0894 pound equivalent live steam

per pound juice per hour, in favor of the projected system. This is a saving of 21.08 metric tons coal per day, or $26,350 per 125 days grinding.

With this turbine in service, there will always be required a small amount of live steam for the normal evaporating load, and there will rarely be occasions of excess exhaust. We expect that it will prove to be the most economic scheme for the factory.

Since a pre-evaporator installed under the discussed system, completely erected with its accessories, will cost about $25,000, it is our opinion that it is a worthwhile investment to be made in any sugar factory. Its cost may be saved almost completely in just a year of grinding.

A paragraph of explanation before I close. The amount in dollars that we claim may be saved in a year of grinding, we don't mean it to be necessarily in dollars. The saving made will appear in the value of the coal economized during the year and in the value as a fuel of the bagasse pile left over as excess.

To those interested in this matter, the tabulations of results given in this paper may be helpful in some other considerations that come along with the problem, but that I do not deem proper to discuss now. Our aim has been merely now to call your attention to the distribution of the steam load in the factory and to the large saving that may be made in fuel consumption, if schemes are worked toward the diminution of the steam consumption in the evaporating and graining stations of the factory.

PORTO RICAN CANE-GRUBS AND THEIR NATURAL ENEMIES, WITH SUGGESTIONS FOR THE CONTROL OF LAMELLICORN LARVAE BY MEANS OF WASP-PARASITES (SCOLIIDAE)

PORTO RICAN CANE-GRUBS AND THEIR NATURAL ENEMIES,

WITH SUGGESTIONS FOR THE CONTROL OF LAMELLICORN LARVAE BY MEANS OF WASP-PARASITES (SCOLIIDAE) *

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INTRODUCTION

The insects known as "White Grubs" are the larvae of a group of Beetles technically named *Lamellicornia* (sometimes referred to as *Scarabaeidae*), characterised by the peculiar formation of the antennae or feelers in the adult; the apical segments of the antennae are flattened out at right angles to their length to form thin leaf-like plates or lamellae. The Lamellicorn beetles occur in all parts of the world, but their numbers are more abundant and the species more varied in the Tropics than in temperate regions. Among them are included many of the worst pest of the world's food-crops of both tropical and temperate parts of the globe, but, principally owing to the fact that crop-rotation is less practised in the former, the damage due to Lamellicorn larvae is generally more severe in these parts than in cooler climates, as exemplified in those species that attack the Coconut Palm (*Cocos nucifera*, L.) and the Sugar-cane (*Saccharum officinarum*, L.).

The *Lamellicornia* are classified into about a dozen families, two of which include the species whose larvae attack sugar-cane; these are (i) the *Melolonthidae* (May-beetles, June-bugs, or Brown Hard-backs), and (ii) the *Dynastidae* (Rhinoceros Beetles, Black Hard-backs, etc.). In each of these families many thousands of species have been described and studied from all parts of the world, and include the sugar-cane grubs of Australia, Mauritius, India, Hawaii, South America and the West Indian Islands. In the countries metioned, with the exception of Mauritius and Hawaii, the cane-grubs are the larvae of indigenous species of beetles that have adapted themselves to feeding upon the sugar-cane. Mauritius suffers from the attacks of a species that was accidentally introduced from the island of Barbados some years ago, without the parasite which kept it in

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PLATE I

FIG. 1.—Relations between the Food-plant, Pest, Parasite, and Hyperparasite (Del. D. Wilson)

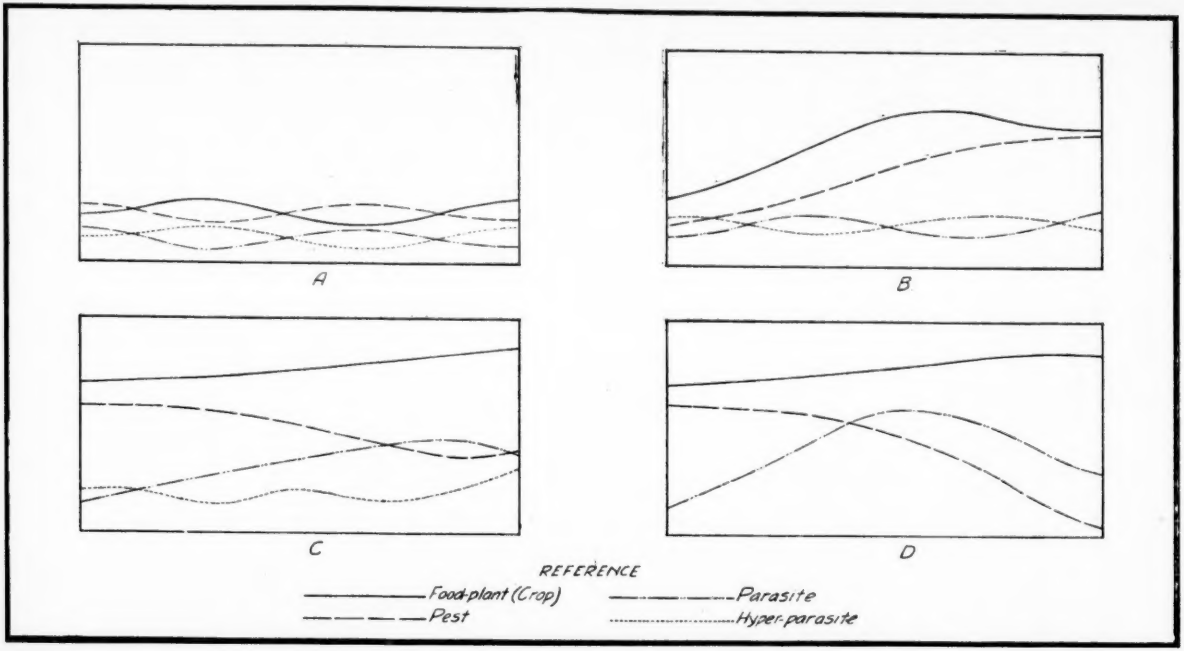


Diagram A illustrates the primeval conditions prevailing before the advent of mankind's agricultural methods, viz., a perfect "balance" between the plant, "pest", parasite, and hyperparasite, with no one of them predominating. Santo Domingo today.

Diagram B illustrates the increase of the pest with that of its food-plant, while the parasite is still kept down by the hyperparasite. Porto Rico today.

Diagram C illustrates the effect of an artificial increase of the parasite, so that its numbers enable it to partially overcome the pest before its hyperparasite can increase in ratio. Our problem.

Diagram D illustrates the effect of the introduction of a parasite which has no rapid increase; eventually its numbers gradually diminish with those of the past. This has occurred several times in Hawaii.

(NOTE: *The gradual rise in the curve of the "food-plant" should be taken as representing an increase in the product for which the plant is grown.*)

check in its native home, so that considerable loss was sustained before it was eventually brought under control. The canes of Hawaii were in a similar way attacked by a Lamellicorn that was inadvertently imported from Japan. In each of these instances the pest was stopped from further unlimited increase by the importation of parasites from its original habitat.

THEORETICAL CONSIDERATIONS

Prior to the planting of sugar-cane, the native species of beetles, which today are pests, took their place in the "Balance of Nature", feeding at the roots of such wild graminaceous plants as they could find, their numbers being kept from increasing by the limitation (partly by themselves) of their food-plants and the incidence of their natural enemies. Chief among the latter were sundry species of insect parasites, which were unable to exterminate the beetles as they were themselves kept in check by their "hyper"-parasites. This state of affairs is represented in Diagram A, Fig. 1, and is illustrated today in the biological status of certain insects in the eastern part of the island of Santo Domingo, paralleling pre-Columbian days in Porto Rico.

With the upsetting of the "balance" by the cutting down of virgin vegetative formations and the planting of large areas under one crop, providence was made for an almost unlimited supply of food for the pests, no account having been taken of a corresponding distribution of the plants favored by their parasites, with the result that the pests have been enabled to increase to such an extent that today their ravages are causing losses of millions of dollars to the world's sugar-industry. The parasites were prevented from increasing in proportion to the pests owing to two powerful factors: (i) the restriction of their breeding places through the gradual disappearance of their food-plants, and (ii) the existence of their hyperparasites, which, being independent of the introduced artificial conditions, retained the same relative proportions to the parasite that they held before the change took place (Diagram B). It will thus be seen that any means by which the numbers of the parasites can be raised *without a corresponding increase in the numbers of the hyperparasites,* will so enable the former to gain a temporary, or even permanent, ascendency over the latter, that a reduction in the numbers of the pest in direct ratio to such increase should follow (Diagram C).

It frequently happens that a parasite can be brought in from

PLATE II.—VIEWS IN SEIBA PROVINCE, DOMINICAN REPUBLIC

FIG. 2.—Normal condition; unfavorable to the enemies of cane pests: Miles of canes unbroken by bush or trees. (Photo. H. E. Box)

FIG. 3.—Unusual condition: favorable to the enemies of cane pests: In this instance virgin forest is (of necessity, not choice) left on a hill-slope not adaptable for growing cane. Small blocks of original growth left standing, while interfering in no way with cultivation methods, would greatly aid in cane-pest control as they would serve as sanctuaries for parasitic and predaceous enemies, particularly birds. (Photo. H. E. Box)

some other country (in which its benefits are limited through hyperparasitism), which will prove comparatively immune to hyperparasites in the country to which it is introduced, or even entirely free from their attack. Finding an unlimited amount of food-material for its progeny, in the form of the pest, and without external controlling factors, it can rapidly multiply until the decrease in the pest is the cause of its own gradual diminution in numbers. This was illustrated when *Scolia manilae* was brought in form the Philippine Islands to combat *Anomala orientalis* in Hawaii, and the effects of such introductions are represented in Diagram D.

For the successful control of insect pests by means of their natural enemies the two following points are to be observed: (i) if the pest is indigenous, raise the numbers of individuals of its indigenous parasites, and introduce others from abroad which will adapt themselves to attacking it; (ii) if the pest is an accidental introduction, search for parasites in its native home, and introduce these *without their hyperparasites.* While we may feel reasonably sure that the control of at least one of our worst cane pests—the Moth Borer (*Diatraea saccharalis,* F.)—can be obtained by means of introduced parasites, it yet remains to be seen how far we can get if similar measures are brought into play against the white grubs. The writer believes that, with a capital expenditure of less than the annual disbursements for five years in the Island upon the present, costly and ineffective collection of the adults, results could be made to follow after a few years' steady work, and it must not be lost sight of that once a suitable parasite has been found and become established, the parasite can continue breeding upon the pest without further efforts on our part, whereas with other systems of control there is a continual charge to be made every year without cessation. Large-scale operations would be more expensive, though likely to produce better and more speedy results.

INSECTS AND THEIR PROGENY

Under the present caption may be mentioned certain formulae which the writer finds convenient to adopt for computing the progeny of insects in cases where it is known that such progeny are represented by average figures or are constant for each female parent.

If A and B are the numbers of females and males, respectively, produced by one female as her progeny, and the former produce similar numbers of offspring, assuming that there is no mortality

among them, or having discounted such mortality, manifestly the total female progeny, F, of N wasps will be $N\ A^n$ at the end of n generations, while the total number of males, M, will be represented by $N\ A^{n-1}\ B$; therefore the entire progeny, P, of N wasps at the end of the nth generation may be shown as follows:

$$P = F + M$$
$$\text{or } P = N(A^n + A^{n-1}B).$$

Where only a portion of the total progeny of each female reaches maturity, A and B in the above equation must be replaced by $(A - X)$ and $(B - Y)$ respectively, where X and Y are the sums of the mortalities during the early stages of each sex respectively.

The total progeny of both sexes produced by a given number, N, of females during n generations (including the nth) is calculated as follows:

$$P = N\ [(A + B) + (A^2 + AB) + (A^3 + A^2B) + (A^4 + A^3B) + \ldots\ldots (A^n + A^{n-1}B)]$$

substituting $(A-X)$ and $(B-Y)$ for A and B, respectively, where the mortality is taken into consideration.

In the case of the Scoliid wasp parasites which form the subject of the present treatise, P, in the last equation, is equal to the total number of white-grubs killed by N parasites and their progeny up to and including the nth generation..

There have been under observation at Aguirre a number of individuals of a wasp, *Dielis trifasciata*, F., parasitic on the sugar-cane grub *Lachnosterna portoricensis*, Smyth, and from data based upon rearing four successive generations of these parasities we can assume the factor A in the above equations to be 4, while B may be considered equivalent to 8. These figures are quite reasonable, for many of our egg-laying females have produced up to 15 females and 30 males as their progeny, and half of each of these numbers would still be a conservative average. Each individual wasp requires to consume one grub for its development to the adult form.

From the foregoing, we can see that at the end of one year, on a basis of six weeks per generation, the female progeny of each individual female should be

$$4^8 = 65{,}536,$$

while the total number of grubs killed (or total offspring of the original female) during the eight generations, would be,

$$(4+8)+(16+32)+(64+128)+(256+512)+(1{,}024+2{,}048)+(4{,}096+8{,}192)+(16{,}384+32{,}768)+(65{,}536+131{,}072)$$
$$=12+48+192+768+3{,}072+12{,}288+49{,}152+196{,}608$$
$$=262{,}140.$$

In nature, of course, the progression is far from even, as there are many outside factors which come into play, causing a fluctuation in the progeny of one generation from that previous to it. Also, complicated mortality factors must be taken into consideration, these being governed by climatic conditions, prevalence or non-prevalence of natural enemies, and the fact that every female is not certain to find food for her progeny. Nevertheless the formulae given above, which apply more or less equally to either pest or parasite, serve to demonstrate the rapidity with which an insect can spread if there is nothing to check it. With certain injurious insects, *e. g.*, the Aphids, the factor *P* would probably run into hundreds of millions at the end of one year if every individual developed and each female was able to oviposit at her full capacity. All epidemics of animal or vegetable organisms can be explained by means of formulæ similar to the above examples, where a geometrical progression occurs.

HABITS AND LIFE-HISTORIES OF LAMELLICORN BEETLES

There is very little variation in the general mode of life among of various species of Lamellicornia, although of course geographical, climatic, and biological factors cause greater or lesser divergences from the normal habits of the various species, and in the periods of their life-cycles. Roughly, the species in which we are interested may be divided into two groups: (i) those whose larvae feed upon the growing root-systems of living plants, and (ii) those whose larvæ feed upon injured and decaying plant tissue and other vegetable matter; in Porto Rico these groups coincide with the two families Melolonthidae and Dynastidae respectively. The following account of the life-history applies to a typical Melolonthid:

The beetles fly at night, and mating and oviposition are carried on after dark; the eggs are laid singly in the soil, sometimes near the surface, but often at a depth of a foot or even more, but invariably in close proximity to the roots of such plants as the larvae will feed upon. Each egg is enclosed in an earthen cell constructed around it by the parent female in such manner that its minimum surface comes into actual contact with the sorrounding soil, and with sufficient room to allow for an expansion which takes place in

the dimensions of the egg. The egg hatches about two weeks after being laid, and from it there emerges the larva, or "white grub" as it is called, which for the first part of its existence sustains itself upon the humus present in the soil. During the larval period there are three distinct stages, or *instars*, each terminating in a complete *ecdysis*, or casting of the skin. The first instar occupies about five weeks, the second instar about eight weeks, while the third and final instar requires about six months; it is during the third instar that the grub does the greatest amount of damage. The grub at this stage is white and soft-bodied, except for the head and legs, which are composed of hardened *chitin*, and are dark reddish-yellow in color; the body is more or less covered with numerous *setae*, or short bristles, the arrangement of which, especially in the pygidial region at the posterior end of the abdomen, is characteristic of the species. The body is curved and appears to be heaviest behind, so that the grub can only with difficulty walk with its legs; it is almost helpless unless surrounded by soil. (In this respect the Porto Rican Melolonthids differ from the Dynastids, whose larvae are able to crawl at quite a good pace, even upon smooth surfaces.) When fully fed, the larva digs deeply into the ground and constructs an oval cell around itself, within the protection of which it rests awhile, later changing to the pupal stage, which occupies about three weeks; it is during the pupal stage that the organs of flight and the organs of reproduction are developed. At the end of the pupal period the insect undergoes another ecdysis, the adult beetle emerging from the membranous pupal shell. Adults frequently remain within the cell underground for several weeks before coming to the surface to carry on the propagation of the species. In the majority of cases, the life-cycle of the Melolonthids occupies nine or ten months, there being one generation annually, but many of the Dynastids, on the other hand, finish their entire development within three months while some foreign species need three years for their complete metamorphosis. A knowledge of the details of the life-cycle, and especially of the seasonal distribution, of each species is absolutely essential before its biological control can be accomplished, and fortunately, in Porto Rico we have available the results of the studies of these subjects made by Mr. Eugene G. Smyth, one of the entomologists attached to the Río Piedras experiment station in the early days of its establishment.

The habits of the adult Lamellicorns show considerable variation in different countries, but it may be stated that in general those of the Melolonthidae feed upon the foliage of certain trees, while those

of the Dynastidae prefer succulent stalks of plants, *e. g.*, sugar-cane or decaying plant tissues. During the hours of daylight the adults are to be found underground, and a habit characteristic of the Porto Rican Melolonthids of the genus *Lachnosterna* is that of congregating in numbers in the soil at the base of wooden posts, trees, etc. Positive phototropism is shown by nearly all species, but generally the Dynastids are more readily attracted to artificial light than are the Melolonthids. During hours of daylight a negative phototropism is exhibited, with a pronounced tendency to positive geotropism.

THE SUGAR-CANE WHITE GRUBS OF PORTO RICO

The Lamellicorn beetles whose larvae attack sugar-cane in Porto Rico may be conveniently classified as follow:

A. MELOLONTHIDAE:
1. *Lachnosterna* * *portoricensis*, Smyth
2. *Lachnosterna vandinei*, Smyth
3. *Lachnosterna guanicana*, Smyth
4. *Phytalus*** *apicalis*, *Blanchard* (=P. *insularis*, Smyth)

B. DYNASTIDAE:
5. *Strataegus titanus*, Fabricius
6. *Ligyrus tumulosus*, Burmeister

DISCUSSION OF THE PORTO RICAN CANE-GRUBS

In the following, the dimensions and periods of the life-cycles have been taken from Mr. Smyth's publications.

1. *Lachnosterna portoricensis*, Smyth

Dimensions in millimeters:

Adult	17–23
Egg	3. 0 × 1. 75
Larva, 1st instar	6–18
Larva, 2nd instar	18–30
Larva, 3rd instar	30–48
Pupa	25–29 × 11–13. 5

* The generic name *Lachnosterna* is adopted throughout this paper in preference to *Phyllophaga* on the authority of Mr. G. J. Arrow, an expert on the group. Mr. Arrow states (Bull. Ent. Research, XI, 1920, p. 189).

"In recent American works on this group of beetles the generic name *Phyllophaga* has been adopted. This name was introduced by Harris in 1826. . . . . It is, however, a *nomen nudum*, accompanied by no description, and is therefore upon the same footing as the numerous catalogue names printed by dealers and others, to which obviously no scientific value can be attached."

Messrs. C. W. Leng and A. Mutchler, of the American Museum of Natural History, employ the name *Lachnosterna* in their standard Catalogue of West Indian Coleoptera (Bull. Amer. Mus. Nat. Hist., XXXIII, Art. XXX, 1914, p. 440).

** Mr. Arrow (*ibid*) includes *Phytalus* in *Lachnosterna*, and gives good reasons for doing so, but in the present paper the writer prefers to use a nomenclature conforming to the American catalogue above referred to. (Messrs. Leng and Mutchler separate the two genera, and include *apicalis*, Blanch. in *Phytalus*.)

This species is found all over the eastern part of Porto Rico on both north and south coasts, and in the interior; its most westerly limit appears to be near Ponce on the south coast. It is the one causing the greatest actual loss to the Island's cane industry, and the one against which the greatest effort has to be made at control.

The natural enemies of *L. portoricensis* are chiefly predators, among which birds, lizards, and carnivorous beetles are the most useful. Two parasites, both of them flies (Diptera) of the family Tachinidae, attack the adult in the moister parts of the Island; these flies are *Cryptomeigenia aurifascies*, Walton, and *Eutrixoides jonesii*, Walton. Another fly, *Sarcophaga robusta*, Aldrich, has been bred from the grubs of *L. portoricensis;* this parasite also attacks caterpillars, grasshoppers, and occasionally the *changa* (*Scapteriscus vicinus*, Scudd.) Hitherto no wasp parasites of the larva have been known to occur in Porto Rico, but the writer has been able to demonstrate that the third-instar grubs are the host of the Scoliid wasp *Dielis** *trifasciata*, F., and are also liable to attack by *D. dorsata*, F. and *D. pyrura* Roh. The second-instar grubs have been found to serve as host for another Scoliid, *Elis xanthonotus*, Roh., but it is not known for certain whether they are normal host of that parasite. It is not improbable that *L. portoricensis* is the host of *Elis ephippium*, F., a wasp closely related to *E. xanthonotus*.

	Maximum	Minimum	Average
Life-cycle in days:			
Egg stage	15	12	13.5
Larva, 1st instar	40	26	32
Larva, 2nd instar	93	43	61
Larva, 3rd instar	174	164	169
Pupa stage	23	20	21.5
Total life-cycle, from egg to adult	345	265	297

2. *Lachnosterna vandinei*, Smyth

Dimensions in millimeters:	
Adult	17–22
Egg	2.97 × 1.7
Larva, 1st instar	6–17
Larva, 2nd instar	16–28
Larva, 3rd instar	27–45
Pupa	23–27 × 10–12

L. vandinei is the analogue in the west of Porto Rico to *L. portoricensis* in the east, and is responsible for considerable damage to

* See footnote on page 85.

sugar-cane on properties situated between Mayagüez and Ponce. Nothing has been recorded in Porto Rican literature as to its larval parasites, but the writer believes that these, as well as the parasites of the adult and the predaceous enemies, are the same as those of *L. portoricensis*.

	Maximum	Minimum	Average
Life-cycle in days:			
Egg stage	16	10	14
Larva, 1st instar	59	17	36.5
Larva, 2nd instar	103	26	47
Larva, 3rd instar	226	78	183
Pupa stage	26	17	21.5
Total life-cycle, from egg to adult	430	148	302

3. *Lachnosterna guanicana*, Smyth

Dimensions in millimeters:	
Adult	13–17
Egg	2.05 × 1.2
Larva, 1st instar	4.5–12
Larva, 2nd instar	12–20
Larva, 3rd instar	20–32
Pupa	18 × 7.9

This species, as its specific name implies, is distributed around the Guánica section, where it was estimated by Mr. Smyth to be one-tenth as abundant as *L. vandinei*. It parasitic enemies, if any, are unknown, but it is probable that it is attacked by the same predators that assist in controlling *L. portoricensis* and *L. vandinei*. There is some suggestion, in the writer's opinion, that this grub is the host of a species of *Tiphia* which has been found in the Guánica district.

Lachnosterna guanicana is almost identical in size with a Barbadian Melolonthid, *Phytalus smithi*, Arrow, and there can be little doubt that it should lend itself to control by a Scoliid wasp, *Tiphia parallela*, Sm., which keeps down the numbers of *P. smithi* in Barbados.

	Maximum	Minimum	Average
Life-cycle in days:			
Egg stage	19	11	13.5
Larva, 1st instar	35	13	24
Larva, 2nd instar	39	23	31
Larva, 3rd instar	221	138	178
Pupa stage	(22)	(22)	(22)
Total life-cycle, from egg to adult	336	207	268.5

4. *Phytalus apicalis*, Blanchard (*insularis*, Smyth)

Dimensions in millimeters:	
Adult	9.5–11.5
Egg	1.45 × 0.90
Larva, 1st instar	3.5–8
Larva, 2nd instar	8–14
Larva, 3rd instar	14–22
Pupa	9 × 11

The adult of *P. apicalis* is commonly called the "Little May-Beetle", and is the smallest of the Porto Rican Melolonthids. It will be seen that in size the mature grub of this species is similar to the average 2nd-instar grub of either *L. portoricensis* or *L. vandinei*, with which it can readily be confused. Mr Smyth records the following differences in the dimensions of the head in these grubs:

Width of head in 2nd-instar *L. portoricensis*	3.45 mm.
Width of head in 2nd-instar *L. vandinei*	3.32 mm.
Width of head in 3rd-instar *L. apicalis*	2.63 mm.

Phytalus apicalis is distributed all over Porto Rico, and its larvae often occur in company with those of the larger Melolonthids. Mr. Smyth states that this species is less common in the Guánica district than *L. vandinei*, but on the region of the south coast familiar to the writer, extending from near Fortuna to Guayama, it is the commonest species, being on an average two or three times as abundant as *L. portoricensis*. Owing to its small size, *Phytalus apicalis* is not generally reckoned as being of great importance as a cane pest, but, on the south coast its dimensions are amply compensated for by its great numbers, ranking the species as one of decided economic importance.

In addition to the usual predators, *Phytalus apicalis* is attacked in Porto Rico by the Scoliid *Elis haemorrhoidalis*, F.; mortality through this agency sometimes amounts to as high as 65 per cent. The wasp is controlled by a hyperparasite, *Anthrax gorgon*, F. (Bombyliidae).

Life-cycle in days:	Maximum	Minimum	Average
Egg stage	12	10.5	11.5
Larva, 1st instar	39.5	21.5	30
Larva, 2nd instar	54	37	45.25
Larva, 3rd instar	197	191.5	194.25
Pupa stage	(20)	(20)	(20)
Total life-cycle, from egg to adult	322.5	280.5	301

5. *Strataegus titanus*, Fabricius

Dimensions in millimeters:

Adult	35–45
Egg	3–4. 5 × 3. 5–5. 2
Larva, 1st instar	8–25
Larva, 2nd instar	25–45
Larva, 3rd instar	45–70
Pupa	30 × 40

The adult of this species is known as the "Sugar-cane Rhinoceros Beetle", on account of the fact that the head of the adult male is provided with a short up-turned "horn", suggesting that of the animal after which it is named. Another species (*S. quadrifoveatus*, P. de B.) occurs in Porto Rico, which seldom if ever is found in canefields, confining its attack for the most part to coconut palms. *S. titanus* normally feeds in decayed or decaying tree trunks, but owing to the rapid deforestation of the southern part of the Island, *S. titanus* has adapted itself to a diet of sugar cane, upon the subterranean portions of which its larvae feed. It is open to doubt whether perfectly healthy cane-stools are attacked by *Strataegus*, it being more probable that this insect follows on after the stools have been injured by either *Lachnosterna* or *Phytalus*, or by lack of moisture. The fact remains, however, that one maturing larva of *S. titanus* can completely ruin a cane-stool, necessitating its replanting, and the species should consequently be regarded as one of the major sugar-cane pests of Porto Rico. In several instances the writer has found as many as five fully grown larvae of *S. titanus* in one stool of cane in heavily attacked localities.

No insect parasites have been recorded as attacking *Strataegus titanus* in Porto Rico, but Mr. G. N. Wolcott remarks that the rare black wasp *Dielis atrata*, F.,* on account of its large size, cannot have any host of sufficient size for its development other than the species of *Strataegus*, an observation that has now been confirmed experimentally by the writer by means of living *D. atrata* brought in from Santo Domingo; it has been found that these wasps readily parasitize the third-instar larvae of *S. titanus*, and therefore should be regarded as very desirable to firmly establish in this island, which can be accomplished by means of introductions of the wasp in large numbers from the Dominican Republic, followed on by breeding work this end.

Mr. Smyth states, with reference to *S. titanus*, that—

* See footnote on page 91.

"Besides Porto Rico, this beetle has been recorded as occurring in Cuba, Jamaica and the Virgin Islands. It has also been collected in Vieques and in Santo Domingo."

The writer was not able to ascertain which species of *Strataegus* (for there are several) is the normal host of *Dielis atrata* in Santo Domingo, but *S. titanus* was collected in the same localities where *D. atrata* was found.

Life-cycle in days:	Maximum	Minimum	Average
Egg stage	21	15	17
Larva, 1st instar	72	24	40.5
Larva, 2nd instar	85	43	72
Larva, 3rd instar	282	137	199
Pupa stage	29	22	24
Total life-cycle, from egg to adult	289	241	352.5

6. *Ligyrus tumulosus*, Burmeister

This Dynastid, although not actually a serious pest of sugar-cane, is deserving of inclusion here, owing to its inter-relations with certain parasites of the noxious species of *Lachnosterna*.

The adult, which may be known as the "Rough Black Hardback", occurs commonly, though seldom abundantly, throughout the year, the species having a short life-cycle (see below), with three or four generations annually. The eggs are deposited in soil rich in organic matter, or in stable manure, upon the humus of which all stages of the larvae feed, although the more mature grubs will consume the decaying portions of old cane stools, rotten wood, etc., and are sometimes so abundant in the old stools left in the "banks" between the rows of growing canes that damage to the crop is frequently—though seldom correctly—attributed to them. Under exceptional conditions, such as periods of extended drought, the grubs are driven to attack the underground portions of growing canes, owing to the absence of other moisture-bearing food, but such occurrences are so rare that no special control efforts are necessary against *L. tumulosus* in Porto Rico. It frequently happens that laborers are encouraged to collect the grubs of this species, being paid for them at the same rate as if they were *Lachnosterna;* planters should learn to distinguish between the harmful *Lachnosterna* and the comparatively harmless *Ligyrus*, as considerable sums of money could thereby be saved, or better still, devoted to more useful methods of insect control work.

Ligyrus tumulosus occurs commonly in the island of Barbados,

and the writer found some examples * of what appear to be this species at Central Romana in the Dominican Republic.

In Porto Rico, as well as in Barbados, the third-instar grubs of *L. tumulosus* are very heavily parasitized by the Scoliid *Dielis dorsata*, F., a wasp that also occurs in Brazil and the Guianas, in which countries it attacks species of *Ligyrus* (*L. ebenus*, Burm. and *L. gyas*, Er.). In Porto Rico *D. dorsata* is so abundant that it would surely be able to exterminate *Ligyrus* were it not itself heavily hyperparasitized by certain flies, chief among which is the Bombyliid *Anthrax lucifer*, F., in spite of which, however, the wasp succeeds in periodically reducing the numbers of *Ligyrus* grubs in each locality to almost the zero point.

Life-cycle in days:	Average
Egg stage	13
Larva, 1st instar	13
Larva, 2nd instar	15
Larva, 3rd instar	27
Pupa stage	14
Total life-cycle, from egg to adult	82

Two other Dynastids—*Dyscinetus barbatus*, F. and *D. trachypygus*, Burm.—occur in Porto Rico, but neither of them seems to be associated to any great extent with the sugar-cane crop of the Island; the larvae of *D. trachypygus*, however, have been recorded by Mr. Smyth as damaging cane roots. The species are worthy of mention, however, as in British Guiana others of the same genus (*D. geminatus*, F. and *D. bidentatus*, Burm.) act as hosts of *Tiphia parallela*, a wasp that it is very desirable to introduce into Porto Rico, and for the establishment of which the grubs of the native species of *Dyscinetus* might very well serve.

SEASONAL DISTRIBUTION OF PORTO RICAN MELOLONTHIDAE

A glance at Fig. 2 will serve to show how the various stages of *Lachnosterna* are distributed throughout the year. The adults (*caculos*) commence to appear in numbers early in April, and continue to occur abundantly until towards the end of August, being most abundant in June and July. There are, however, always a few

* These have since been sent to the Imperial Bureau of Entomology, London, and, though not specifically determined, were found to be distinct from the Porto Rican *L. tumulosus*.

PLATE III

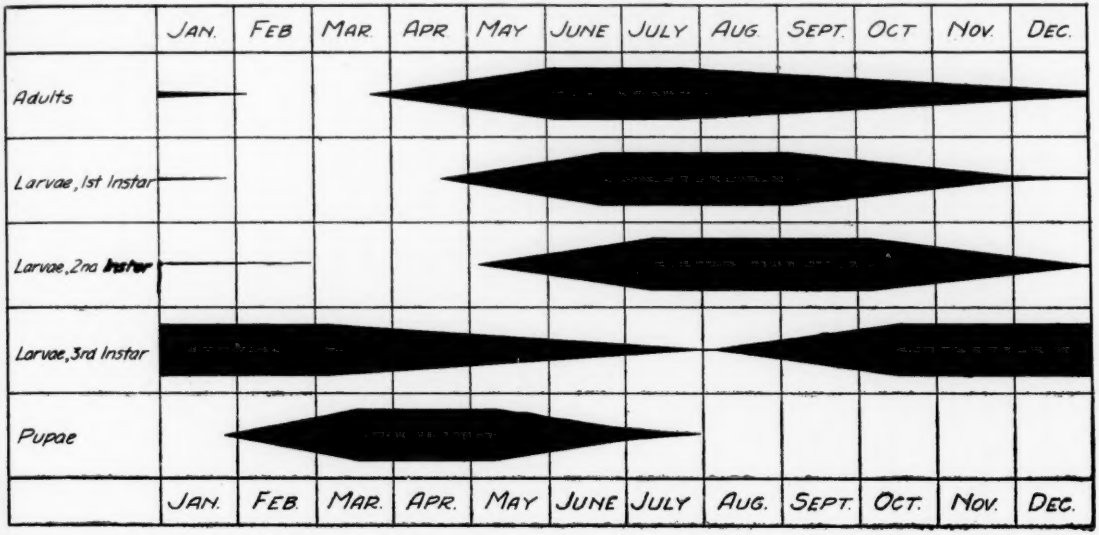


FIG. 4.—**Seasonal Distribution of Porto Rican Melolonthidae.** (Del. D. Wilson)

(NOTE: *The thickness of the bar denotes relative abundance.*)

"stragglers" which remain until sometimes as late as January. The first-instar grubs are consequently most often met with in the cane-fields from the middle of April until early in September, while the second-instar larvae are seldom found before the first weeks of May, continuing to be common until early in October. The destructive third-instar grubs commence to make their appearance during August, reaching their maximum abundance from November until February, gradually diminishing in numbers until in June and July very few can be found. It will be seen that the period of the maximum abundance of the third-instar, the stage most responsible for damage to the crop, coincides with the most critical stage in the growth of late *primavera* cane, which generally suffers more from grub attack than does *gran cultura*. It is not yet known why *caculos* select certain fields for egg laying, but it is reasonable to suppose that the chief factors concerned are (i) the proximity of trees upon the foliage of which the adults feed, and (ii) the height of the cane, for they do not appear to oviposit to any great extent in fields of canes over three feet in height.

(NOTE: The thickness of the bar denotes relative abundance.)

THE CONTROL OF CANE-GRUBS IN PORTO RICO

Since 1911 the problem of the control of cane-grubs has constantly received the attention of the entomologists of the Experiment Stations in Porto Rico. Through the failure to obtain results with certain wasps that were introduced from the United States way back in 1911 and 1913,* this line, which the writer considers the most promising angle of attack against the pest, has been practically abandoned, and attention turned to the possibilities of effecting the control of white grubs by means of fumigants applied to the soil. Mr. Wolcott has experimented in detail with several promising substances, including carbon bisulphide and its emulsion, calcium cyanamide, and para-dichlorobenzene (P.D.B.), none of which gave the desired results, or, doing so, were found too expensive to apply upon a plantation scale. At Aguirre the writer has experimented with P.D.B. and also "Cyanogas" (calcium cyanide), a sample of the latter product being received from the American Cyanamid Company, 511 Fifth Avenue, New York City. The experiments were carried out in heavily infested B.H. 10(12) *gran cultura* cane in which an average of thirty-five grubs occurred around each stool.

* See pages 100–101.

It was found that either of the substances tried was effective in killing up to eighty-five per cent of the grubs when applied at the rate of one ounce per stool, the chemical being lightly scattered over the soil for a radius of nine inches from the center of each stool; the soil was slightly broken both before and after the chemical was applied, and the application was followed by a moistening of the soil with irrigation water. The results obtained suggest the desirability of further trials on properties where fumigation is considered likely to prove a practicable proposition.

No doubt, where large numbers of grubs occur in limited areas, some method such as the above might be found economical, but the expenses should be chargeable to the immediate crop of the areas so treated.

For the control of white-grubs where they occur over wide areas, other means must be found more practicable, especially to the small farmer, and in consequence, the only attempts that are now being made at control are the collection of grubs when fields are being ploughed, and the collection of adult beetles during the epochs of their maximum abundance and even these oparations cannot be said to be done upon anything like a satisfactory scale, partly owing to the independence of the laboring classes in many districts, but also due to a spirit of *laissez-faire* prevailing among many elements of the planting community.

On the larger properties, especially upon the south coast, the work of collecting *caculos* is included in the regular routine operations of the field administration, but even so the collections are made intermittently and more or less at random, no really systematic campaign being considered practicable under existing conditions.

Mr. E. H. Barrow points out in a recent publication that the administration of one of the larger concerns operating on the south of Porto Rico spent approximately $15,000 upon some six million grubs and four million adults of *Lachnosterna* during the five years 1919 to 1923 inclusive. Such collections, although aparently large, represent no more than a "drop out of the bucket". Though a certain amount of good must necessarily follow, it is felt that such is out of all proportion to its cost. To obtain any real benefits through a reduction in the annual status of the pest, the collections should be carried out upon a much larger scale than they are at present, and over large areas simultaneously.

To be economical, when a continuous *annual* (as constrasted with a *capital*) expenditure upon insect-pest control is made, such should at least be equal to the benefits obtained the next year; otherwise there is an actual loss through the transaction. With sugar at, say, five cents, the expenditure quoted above represents an equivalent value to approximately 1,350 tons of cane; that is to say, the destruction of two million *Lachnosterna* annually should have caused a saving of 270 *tons of cane* each following year to justify its cost, which we venture to doubt was actually the case.

For comparison it may be of interest to record that when the canefields of Mauritius were seriously threatened some years ago through the ravages of *Phytalus smithi*, a Melolonthid that was accidentaly introduced into that Island from Barbados, the Government issued an order in 1915, which reads:

"PLANT DISEASE PROCLAMATION (AMENDMENT)

"It shall be lawful for the Director of Agriculture, when the numbers of beetles are in great abundance, to require any proprietor, manager, or lessee of land to furnish, for collection of insects upon their lands, one-third of the total number of their engaged labourers per night; and if these labourers are not furnished an equivalent number of men may be employed by the Director of Agriculture and the charge made against the proprietor, manager or lessee."

As a result of this somewhat stringent (though necessary) measure, the following numbers of adult *Phytalus* were obtained:

1915–16	42, 511, 241
1916–17	72, 292, 689
1917–18	70, 035, 663
1918–19	71, 119, 278
1919–20	30, 969, 504
Total, 1915–20	286, 928, 375

The writer considers that unless results like the above can be accomplished by hand collection, a far greater value could be obtained from money spent upon cane-pest control were such sums devoted to fostering and advancing the status of the native parasites of the Island, and in securing other species of these useful insects from abroad.

NATURAL ENEMIES OF CANE-GRUBS IN PORTO RICO

A. Predators.

Although it would be difficult to artificially increase the numbers of the insect predators of Lamellicorn larvæ, a knowledge of them and of their habits is of the greatest importance.

The most useful and generally distributed predator upon white-grubs in Porto Rico is undoubtedly the Elaterid beetle, *Pyrophorus luminosus*, F., known as the "*cucubano*", the elongated yellow larva of which can be found in nearly all fields where grubs occur, feeding upon them in all their stages. The writer had one of these carnivorous larvae kept in captivity and during one week it destroyed twenty-five full grown *Lachnosterna* grubs, and it has been recorded that in Queensland a larva of the Elaterid ***Agrypnus mastersi,*** Pascoe, killed and consumed 230 cane-grubs in 17 months.

It is a matter for regret that on many sugar estates in Porto Rico no discrimination is made between this useful insect and the grubs which it destroys, although it in no way resembles a white grub, for numbers of *cucubanos* are collected by the boys who search for grubs and are paid for at the same rates as the latter. Unless laborers (and those of higher responsability, too) can be taught not to destroy such beneficial insects at these beetle larvae, it would be better not to do any collecting at all, for more harm is done than good. Owing to their rapid movements, it seldom happens that these Elaterid larvae fall prey to blackbirds, which in any case would probably reject such unsavory morsels.*

The larvae of the carnivorous Carabid beetle, *Calosoma alternans*, F., rank next in importance, but they are not so frequently seen as those of *Pyrophorus*.

An Asilid fly, whose larva is also carnivorous, is reputed to attack white-grubs in Porto Rico; the writer has met with it upon two occasions in grub-infested cane-fields near Aguirre. These large Diptera are of some importance in the United States, as controlling agents of *Lachnosterna*, but in Porto Rico their value seems almost negligible.

Vertebrate enemies of cane-grubs include birds, of which the most important as a controlling agent is the Porto Rican Blackbird (*Holoquiscalus lugubris*, Cassin), large numbers of which follow ploughing machines, picking up any grubs that are exposed; by examining fields at ploughing time, however, one finds that numbers of the grubs escape, and a fair percentage of those collected by the birds were already killed or injured by the machines passing over them.

Mr. Alex. Wetmore, in his excellent treatise, "The Birds of Porto

* Mr. Wetmore records no instance where *Pyrophorus* was found in the stomach-contents of Porto Rican birds, even when the latter had been feeding in fields heavily infested with cane-grubs, and where in all probability the Elaterids occurred in numbers.

Rico", makes the following observation, worthy of attention: "That birds need shelter as well as protection will not be questioned, and owners of plantations should look carefully to providing this if it is not already present. A long level stretch of cane or tobacco, with not a tree or other obstruction to break its continuity, while a pleasing sight to the agriculturist, offers little encouragement to the bird in search of shelter and food. A similar stretch of cultivated land, with lines of symmetrical royal palms or coconuts along roadways and dense clumps of graceful bamboos adorning the borders of streams, while not losing an iota of its productiveness, will gain an esthetic charm and beauty and provide an attractive feeding ground for birds which will more than repay the owner in the great numbers of injurious insects they consume." The writer is strongly advocating the planting of more royal palms in certain *haciendas* of the Aguirre properties, as the crowns of these trees are the favorite nesting sites for blackbirds, and it is believed that an increase in the numbers of palms will in time lead to the augmentation of the numbers of these useful birds.

Lizards exert an influence upon the status of the grub pest, and Mr. Wolcott records two species, *Ameiva exsul*, Cope and *Anolis cristatellus*, Dum. & Bib., as being known to consume Lamellicornia in Porto Rico. Among the reptile class, however, the Island sadly needs toads, to which Mr. Wolcott draws attention in the following words: "Although the small tree-toads or *coquís* are abundant in Porto Rico, there are no large nocturnal native toads large enough to eat May beetles. Such large toads are found in most of the other West Indies and on the mainland, and keep the number of May Beetles and their larvae, the white-grubs, so reduced that they are seldom pests of cultivated crops." From time to time importations of small numbers of toads into Porto Rico have been made; it is hoped that these will breed, and in any case it is desirable to supplement their numbers by obtaining further supplies from Santo Domingo and elsewhere, in order that each plantation can have its own place for rearing them artificially for distribution, small "toaderies" being established here and there throughout the properties. The importation and establishment of toads should be undertaken by the sugar-cane growers of Porto Rico as their first measure in any campaign against *Lachnosterna* by means of its natural enemies.

B. Parasites.

In addition to a mortality due to attack by parasitic fungi and bacterial diseases, the larval and adult stages of the Lamellicornia succumb to a variety of insect parasites, both internal and external in habit. Several species of these parasites are known to occur in Porto Rico, but none of them, for reasons already explained, are sufficiently abundant to effect any marked control over the Melolonthidae and Dynastidae that attack sugar-cane.

Apart from the wasp-parasites about to be dealt with in detail, there are a variety of fly-parasites upon both larvae and adults of the Melolonthidae, and some of these might well be introduced into Porto Rico to assist the two species (*Cryptomeigenia aurifascies*, Walton and *Eutrixoides jonesii*, Walton) already occurring here. Owing to the mode of life of these flies* and the difficulties attendant upon their propagation by artificial means, large numbers would have to be introduced to effect the establishment of foreign forms.

The most important and generally effective enemies of the Lamellicornia in all parts of the world are the "digger-wasps" of the family Scoliidae, which prey upon the beetle larvae, and it is through their agency that the writer believes the control of Porto Rican cane-grubs will ultimately be obtained.

THE DIGGER WASPS (SCOLIIDAE)

The family consists of a large number of fossorial Hymenoptera which are exclusively parasitic upon the larvae of Lamellicorn beetles, and when one has become familiar with their general aspect, these wasps can readily be distinguished from all other kinds. The characteristic feature of the Scoliidae is the presence of a constriction at the junction of the (apparently) first and second abdominal segments. The females differ considerably from the males both in dimensions and in coloration, some species of Scoliids, *e.g.*, *Dielis dorsata*, F., being sexually dimorphic. The females are stout-bodied wasps, the body being broadest at the posterior end of the thorax and the middle of the abdominal region; the legs are rather short, thickset, and are covered with a heavy armature of short spines which aid the wasp in its digging operations; many parts of the body are covered with a thick velvety pubescence. The males, on the other hand, are slender and are without the conspicuous spines upon the limbs; they are easily distinguished from the females by

* These flies oviposit upon the exposed part of the body of the beetle, when its wings are expanded during flight after dark.

the length of their antennae, which generally equal nearly the length of the body, whereas those of the females are quite short, scarcely equalling the length of the head. In size the Scoliids vary from barely three quarters of an inch in wing expanse (*Tiphia*, etc.) to those with a span exceeding three inches (*Dielis atrata*); the majority, however, have a wing spread of between an inch and an inch and a half. There is considerable variation in color among the different species, some being entirely black, others black with yellow bars across the thoracic and abdominal segments, while not a few of them have clearly defined portions showing bright red, due to pigmentation of either the integument or of the pubescence, or both. The wings of some species are pigmented to show blue or purple reflections when viewed in certain lights, being transparent white or yellow, or translucent blackish ("smoky"), by transmitted light; many species have wings without these iridescent reflections.

The family includes several thousand species distributed in all parts of the world, the number of species in any locality being more or less in proportion to those of the Lamellicornia upon which they breed. Dr. F. X. Williams, an authority upon the group, remarks that the diversity in the Lamellicorn fauna of any district serves as an index to the Scoliidae likely to occur there. Many of these wasps parasitize grubs of little or no economic importance, but, on the other hand, large numbers of potential pests are kept entirely under control through their agency. Some of the Scoliids specialize upon one particular species of grub, while others are not so discriminating, having a wide range of hosts. A typical example of the latter type is *Tiphia parallela*, which attacks the Melolonthid *Phytalus smithi* in Barbados and species of Dynastids (*Dyscinetus*, etc.) in South America. These naturally adaptable species are on the whole more likely to prove useful to Porto Rico than the more specialized types, although some of the latter, when deprived of their normal hosts, will turn their attention to other species of grubs. An example of this kind is *Dielis dorsata*, which normally parasitizes the Dynastid *Ligyrus tumulosus*, but which will work upon such Melolonthids as *Lachnosterna* in the absence of *Ligyrus*.

The Scoliidae consist of several genera, of which *Dielis*, *Elis*, and *Tiphia* are the most likely to include species which may prove beneficial to Porto Rico.

HABITS AND LIFE-HISTORY OF THE SCOLIIDAE

During the early hours of sunshine, from about eight o'clock until eleven o'clock in the morning, the females can be seen refreshing themselves with the nectar of certain flowers*. At mid-day they disappear underground, where they search for their prey. The males, on the other hand, can generally be found above ground at all hours of the day, flying with a series of rapid zig-zag motions in the vicinity of places favored by their mates, settling now and then to imbibe the nectar from wild flowers. A very curious habit exhibited by the males of some genera of Scoliidae is that of congregating together in large numbers towards the late afternoon upon the stems and leaves of wild vegetation; sometimes the males of the common *Dielis dorsata* can be seen in hundreds upon the leaves of the iron-weed or *escovilla* (*Sida carpinifolia*, L.) that abounds in the vicinity of canefields, while those of *Elis haemorrhoidalis*, another common Scoliid, may sometimes be seen in large clusters resting upon the leaves and flowering spikes of the pigweed or *bledo* (*Amaranthus spp.*). In Santo Domingo the writer has seen the branches of young guácimas (*Guazuma guazuma*, L.) hanging low with the weight of thirty or forty males of the large black *Dielis atrata*. Dr. Williams remarks "They may assume odd positions on these weeds, which they grip with their jaws and legs or with the jaws only". The writer thinks that the habit may be some sort of response to the social instinct derived from their ancestors.

The life-history of the Scoliidae constitutes one of the most interesting phases of Insect Life, and its study is fascinating in the extreme.

The female Scoliid would appear to possess extremely powerful olfactory and auditory senses for the location of her prey, as this is carried on out of sight, sometimes at a depth of two feet or more below the surface of the ground. When a grub has been found, the wasp gets busy around it, and, after a short time spent in feeling over it with her very active antennae, proceeds to sting it in one of the large nerve-ganglia that control the locomotor muscles, so that the grub is rendered completely immobile, yet still alive; in this way the mother-wasp insures a supply of fresh food for her offspring, and would seem to have arrived at a higher stage in

* This refers to the strictly anthophilous types. Some Scoliids, chiefly the species of *Tiphia*, do not frequent flowers, but are attracted to the sweet secretions (honey-dew) of scale-insects (Coccidae) and plant-lice (Aphidae) on the leaves of trees or other vegetation.

evolution in this respect than the social wasps (*Vespidae*) that have to bring in freshly-killed prey to the young larvae in the nest, which food, unless immediately consumed, would rapidly decompose.

In the glass jars (Fig. 13, A) employed for rearing Scoliidae artificially the female wasp can be seen to drag the helpless grub down to the bottom of the jar, where a space is cleared around it, the wasp packing the soil above the grub's body to form a roof, the whole forming an oval cell with the paralysed grub resting upon its back in the bottom of the hollow, thereby giving ample room for the wasp's movements during the process of oviposition. It is not known whether under actual field conditions the wasp makes the cell at the point in the ground where she first located and stung the grub, or whether the latter is dragged to a lower level through the surrounding medium. When the wasp is satisfied with the preparation of the home for her future offspring, she wanders around the grub, feeling over it with her legs and antennae, adjusting a limb here and there, or removing a fragment of dirt from its body, and after a few minutes spent in this manner, she adjust her body to the length of that of the grub, grasping the up-turned under-surface of the thorax with her front two pairs of legs, and its head with her jaws, and, bending her flexible abdomen down upon the venter of the grub, moves it about searching for the exact spot (which appears to be free from setae) for the deposition of the egg, which latter operation occupies about a minute. (The writer has several times watched the whole process through the glass walls of the rearing jars). The egg is cylindrical, slightly curved, and has rounded ends; the ratio of its length to its greatest breath is approximately as 4:1. The egg is laid with its longitudinal axis at right angles to that of the grub (Fig. 5, A & B), being glued into position by a fluid secreted by the wasp during the act of laying it. The foregoing applies to wasps of the genus *Dielis*, and some species of *Elis*. The habits of *Elis xanthonotus* are similar, except that the egg is laid towards the posterior end of the grub's abdomen, and flat across the surface of the grub's body, instead of at right angles to it. The species of *Tiphia* do not completely paralyze the host, which recovers from the effect of the sting after the deposition of the egg, and during its crawling movements the latter is sometimes rubbed off; *Tiphia* lays its eggs upon the back of the grub, across the thorax, just behind the head.

The entire operation from the time the grub is first located until the egg has been laid occupies about two hours. It is not known,

and of course impossible to ascertain, how many grubs are parasitized by a female in the course of a day in a state of nature, but under artificial conditions the writer has been able to obtain three eggs from one wasp within the twenty-four-hour period with one of the smaller *Dielis;* two per day however, is a good average for breeding purposes. When the wasp has completed the deposition of the eggs she takes a final look around and departs in search of another grub.

The eggs do not require any great length of time before they

EARLY STAGES OF SCOLIIDAE

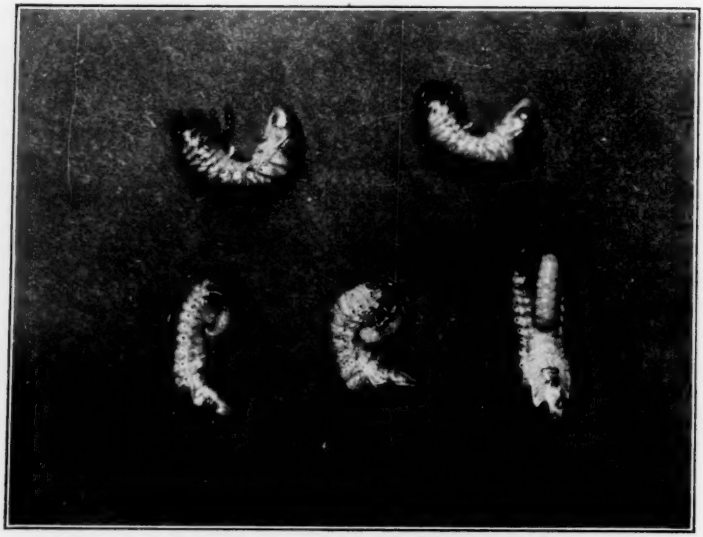


FIG. 5.—Eggs and Larvae of *Dielis trifasciata*, F. upon grubs of *Lachnosterna portoricensis*. Sm. (natural size). (Photo. Rodríguez Serra, Ponce)
A, B—Eggs (lateral aspect)
C—Larva, 3 days old (lateral aspect)
D—Larva, 4 days old (lateral aspect)
E—Larva, 5 days old (dorsal aspect)

hatch; those of *Elis haemorrhoidalis* and *E. xanthonotus* hatch within 32 hours of being laid, while those of *Dielis atrata* take 72 hours for their development; the eggs of *D. dorsata*, *D. trifasciata*, etc., require an intermediate period of about 48 hours. The empty egg-shell is pushed aside by the newly-hatched wasp-larva, after which the latter buries its mouth-parts into the body of the host and the consumption of the internal parts of the grub's body commences.

With unfailing instinct the young wasp avoids injuring those parts of the host's anatomy to which damage would prove fatal. It is probable that an ecdysis occurs before the larva is half-grown, but such has not been observed by the writer. With the increase in the size of the wasp larva there is a corresponding diminution in the size of the host, and when the former is fully fed, nothing remains of the latter but an empty shrivelled skin with the head and legs attached. Wasp larvae in an early stage of development, on being removed from a grub, will commence to feed upon another provided the latter's integument has been pierced. A curious habit of these larvae when nearing maturity is that of ejecting a milky fluid from the posterior extremity when disturbed; this fluid can be squirted to a distance of several inches.

Scoliid larvae are glistening white and they appear to be slimy;

EARLY STAGES OF SCOLIIDAE

FIG. 6.—Cocoons of Scoliidae (natural size)
(Photo. H. L. Dozier)

A—*Dielis* type: adult emerges by means of hinged lid at one end.
B—*Elis* type: adult emerges by means of a ragged hole bitten in one side.

at first they are pear-shaped or almost globular (Fig. 5, C), but later they become elongated and decidedly maggot-like (Fig. 5, D and F.) The fully-grown larva of the smaller Scoliids (*Elis* and *Tiphia*) is about half an inch in length, the larva of the medium-sized species of *Dielis* about an inch, and that of *D. atrata* one and a half inches long when mature. The time spent in the larval stage, feeding upon the paralyzed host, has been ascertained to be from three to four days in the case of *Elis*, seven days in the case of the smaller *Dielis*, and fourteen days in the case of *D. atrata*. The egg and larval stages are of longer duration in cool weather than in warm, and frequent

changes of temperature seem fatal to the Scoliidae in all their early stages.

The wasp-larva, upon completing its development, constructs a neatly made cocoon around itself, the cocoon being formed in two layers, the inner one smooth and shiny on the inside, the outer layer coarser and rough in texture. Pupation occurs within the cocoon, and from four to six weeks are spent in this stage, after which the mature sexually-perfect adult wasp emerges; the time spent in the cocoon depends upon the temperature prevailing. Wasps of the genus *Dielis* emerge by biting a neat lid out of one end of the cocoon, the lid being hinged so that it can be pushed aside by the emerging wasp (Fig. 6, A); *Elis* and *Tiphia* merely gnaw a ragged hole in one side of the cocoon, through which aperture the wasp crawls out (Fig. 6, B).

NATURAL ENEMIES OF THE SCOLIIDAE

Although the Scoliidae suffer to some extent through being preyed upon by vertebrate animals (birds and lizards), and certain carnivorous insects chiefly predacious bugs of the family Reduviidae, as well as spiders, it is the insect hyperparasites that are so largely reponsible for keeping down their numbers; indeed, were it not for these hyperparasites, it is doubtful whether any of the Lamellicornia could ever become pests, so great are the multiplicative powers of the Scoliidae.

Apropos, the following extract from a paper by Dr. J. F. Illingworth, upon the natural enemies of cane-grubs in Queensland, may be of interest:

> "It would be interesting to know what percentage of the Scoliids are destroyed by these parasitic enemies, but unfortunately this is a phase of the problem on which we have no data. Yet, when we consider the comparative abundance of the wasps that are known to prey upon grubs in our cane areas, we are forced to conclude that a very large majority of them must succumb to natural causes. Otherwise, with their prolific reproduction they would be able to hold our cane-beetles in check with no assistance."

There are three main types of hyperparasites upon fossorial Hymenoptera, species of each of which are responsible for checking the increase of the Scoliidae: (i), the Bombyliid flies; (ii) the Tachinid flies; and (iii), the Rhipiphorid beetles.*

* In the United States it is recorded that a Scoliid of the genus *Elis* is hyperparasitized by members of a fourth group—the Mutillid wasps.

THE BOMBYLIID FLIES

A specimen of *Anthrax lucifer*, F., a typical Bombyllid, is illustrated in Fig. 7, A, and the figure serves to show the general aspect of one of these flies. The family includes many hundreds of species distributed over most parts of the world, several of which are hyperparasites upon fossorial hymenoptera. The Bombyliid adults are among the most rapid of all insect fliers, and are commonly to be seen darting or hovering over the surface of the soil, especially in sandy locations, as well as haunting the vicinity of the nectar-bearing flowers that are so attractive to the wasps whose early stage they parasitize.

HYPERPARASITES OF SCOLIIDAE

A B

FIG. 7.—Bombyliidae

A—Adult of *Anthrax lucifer*, F., a typical Porto Rican species (natural size) (Photo. H. L. Dozier)
B—Pupa of one of these flies. (Del. H. E. Box from Davis)

So far as the writer is aware, nothing is known of the mode of life of these flies during their early stages, but the empty pupa cases are very often to be found protruding from punctured Scoliid cocoons. Large numbers of individuals of the commoner species of Scoliids in all stages have been examined by the writer, and, although many cocoons were found with the empty Bombyliid pupa-case (Fig. 7, B) projecting, no instances were noticed of the fly larvae at work upon the immature stages of the Scoliids. How and where the flies lay their eggs (if they are not actually viviparous) is unknown to the writer, but the subject is one worthy of special research. During February, when the writer had about a hundred cocoons of *Elis haemorrhoidalis* under observation at Aguirre, several instances were noted where Bombyliids emerged ten days after the cocoons had

been collected in the fields; the inference is that the immature stages of the Bombyliidæ are spent upon or in the Scoliid after it has spun up, and that their life-cycles occupy ten days at least. At present no further data is available to throw light upon this rather obscure subject.

The Bombyliidae are represented in Porto Rico by numerous species, varying from a little less than a half an inch (the smaller *Anthrax*) to over one and a half inches (the larger (*Hyperalonia*) in the spread of the wings. Not all of them are parasitic upon Scolidae, however, some of them being enemies of the Pompilidae or Spider-wasps (*Pepsis*) and the Sphegidae or Grasshopper-wasps (*Ammobia, Sphex*), etc. In two cases only is the association of a Porto Rican Bombylid with its correct host actually known: (i) *Anthrax gorgon*, F., parasitic on *Elis haemorrhoidalis*; and (ii) *Anthrax lucifer* F., parasitic on *Dielis dorsata;* it is believed that the second instance is a new record for the Island.*

THE TACHINID FLIES

In British Guiana the writer has bred a small species of Tachinid from cocoons of a Scoliid, probably *Tiphia parallela*, Sm., and it is not improbable that in other countries flies of the same family attack similar species of digger-wasps.

Mr. Smyth gives an instance of parasitism of the adult of *Dielis dorsata* in Porto Rico, and states that when found at Santa Rita it contained "a single Dipterous puparium, about 5 mm. long, from which issued, on June 18, 1913, ten small Chalcidids, which have not been determined". It seems probable that the Dipteron referred to was one of the Tachinidae, but Mr. Smyth gives no information upon this point.

The writer trusts he will be forgiven the irrelevancy of reminding his readers how strongly the above instance of tertiary parasitism, or hyperparasitism of the hyperparasite, recalls to one's mind the old tag

> "Big fleas have little fleas
> Upon their backs to bite 'em;
> And little fleas have lesser fleas,
> And so *ad infinitum.*"

THE RHIPIPHORID BEETLES

A group of insects more or less specialized to a habit of parasitiz-

* *Anthrax lucifer* is a primary parasite on certain Lepidopterous larvae in the U. S. A. In this role the fly is beneficial to man. As a parasite of Scoliids it is noxious. H. E. B.

ing the fossorial Hymenoptera, including the Scoliidae, is the family Rhipiphoridae, the members of which are rather small beetles of curious aspect (Fig. 8). The writer found these insects quite commonly in British Guiana upon plants frequented by Scoliids, but has so far not met with them in Porto Rico, although Wolcott lists five monly in Brithis Guiana upon plants frequented by Scoliids, but has here.

It is not known definitely how these beetles succeed in parasitiz-

HYPERPARASITES OF SCOLIIDAE

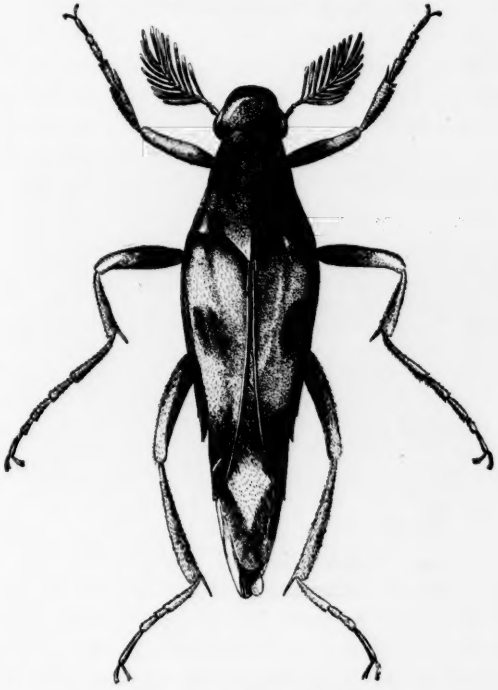


FIG. 8.—Rhipiphoridae
Adult of typical species (3 times natural size) (irom Davis)

ing their host, for they do not appear to go underground in search of them, spending most of their time upon flowers and such vegetation where the wasps abound. Dr. J. J. Davis suggests that the eggs are probably laid on or near flowers frequented by the wasps, or possibly on the body of the wasp itself, and that the egg or the newly-hatched.

Rhipiphorid larva becomes attached to the hairy body of the wasp and is in due course transported to the site of the latter's operations upon a white grub, when it becomes detached. This is very probably the true explanation of what happens, for it is known that a similar ingenious method is adopted by a related family of parasitic beetles —the Cantharidae—whose first-instar larvae (called *triungulins*) are very active, and cling to the hairy bodies of certain bees, being carried by the bees to their nests, upon arrival at which they become detached, cast their skins, and losing practically all power of locomotion, settle down to a parasitic existence upon the bee larvae.

It will readily be understood how important is the quarantining of any Scoliids or other fossorial wasps that are introduced as larvae or cocoons from abroad, in order to prevent the escape of such insects as those mentioned above, for not only is there the danger to the species being introduced, but the foreign hyperparasites might, and very probably would, adapt themselves to attacking the indigenous Scoliids as well as other kinds of beneficial wasps, with disastrous results. The method adopted by most workers is to put each individual Scoliid in a separate tube, within which the emergence of the wasp or its parasites takes place, when the former can be transferred to breeding-cages, the latter being destroyed before they can breed.

PARASITIC FUNGI

In addition to the predators and parasites discussed above, there are certain fungi which cause a heavy mortality among Scoliids, especially during the pupal stage of the wasps. These fungi, principally species of *Isaria*, are the cause of great trouble when the wasps are being reared artificially, and at present no sure means are available for preventing such losses; keeping the cocoons in an atmosphere fairly dry, however, is calculated to reduce the mortality to a minimum, although the atmosphere in which they are kept should not be absolutely dry, a certain amount of moisture being necessary for their development. Infection by fungi has greatly handicapped the rearing of Scoliids at Aguirre, but the writer hopes that with proper facilities these difficulties will be overcome. At certain seasons a fairly high percentage of Scoliids succumb to fungal attack under actual field conditions, which subject has been treated more or less at length by writers in other countries; no data are at present available, however, upon the prevalence, if any, of fungi upon Porto Rico Scoliidae under actual field conditions.

ECOLOGY OF THE SCOLIIDAE; IMPORTANCE OF NECTAR-BEARING PLANTS

More than one observation has been made in this paper relative to the importance of having suitable food-plants available for the successful propagation of Scoliid wasps in a state of Nature, and, although at present the writer does not feel competent to offer more than a few cursory remarks upon it, the subject is one worthy of a great deal of close attention and study. The observations that follow are based for the most part upon the writer's experience upon the South of Porto Rico, and hence should not be taken as necessarily applying to the Island as a whole.

The fact that several of the indigenous Scoliids of Porto Rico

ECOLOGY OF SCOLIIDAE

FIG. 9. — Near Santa Isabel, P. R. *Callejón* **with thick growth of** *Kallstroemia maxima*, **a favorite haunt of** *Dielis dorsata*, **F.** (Photo. H. E. Box)

are common to both the north and the south of the Island suggests that they are fairly adaptable climatologically, and from records in literature, supplemented by observations made by the writer, it appears that they are in a large measure adaptable to the vegetation of the two regions.

The vegetation of the north of Porto Rico differs considerably from that of the arid regions on the south coast, but both districts possess a variety of plants whose flowers prove attractive to many Hymenoptera, especially the Scoliidae. Where irrigation is practiced (and there are few parts where it is desirable to establish the wasps where irrigation is not practiced) the wild plants approximate more closely

to those of the naturally moist regions, but, nevertheless, there is ample room for extending the distribution of such plants as are desirable in order to obtain the maximum benefits from the wasps.*

It often happens that plants which come into flower at certain seasons are, upon the commencement of their fruiting season, not always succeeded by the appearance of other suitable flowers, so that the wasps, in order to obtain the nectar so necessary to them, are forced to temporarily quit these localities and migrate to places where suitable flowers are to be found. It is believed that with proper study this state of affairs can be adjusted, and a succession of nectar-bearing flowers made to appear throughout the year, by

ECOLOGY OF SCOLIIDAE

FIG. 10.—Near Salinas, P. R. Similar spot to Fig. 9, where both *Dielis dorsata*, F. and *D. trifasciata*, F. occur. (Photo. H. E. Box)

planting, or at least encouraging, certain types of insect-fertilized plants; the subject, however, require a much greater amount of study than the writer has so far been able to devote to it.

On the south of Porto Rico there are two plants of special interest in this connection. The first of these is *Commicarpus scandens*, Linn. (Stand.), known locally as "*pega-pega*", which is a stick-seeded vine of somewhat dense growth belonging to the order Nyctaginaceae, and occurs in more or less abundance upon the fences bordering plantation roads (Fig. 11). The flowers are quite small, about an eighth of an inch in diameter, pale yellow in color, and are borne upon

* The writer is attempting to propagate artificially a somewhat rare species of *Paullinia*, the flowers of which are very attractive to anthopilous Hymenoptera.

inflorescences measuring about one inch in diameter; towards dusk their aroma is perceptible. On sunny mornings large numbers of insects are to be seen in the vicinity of these vines, imbibing nectar from the flowers; the majority of the insects will be found to be bees and wasps, and among the latter the Pompilidae and Scoliidae easily predominate, the former being represented by *Pepsis* and *Psammochares*, both of which prey upon spiders, while the Scoliids are represented by *Elis* and *Dielis*.

Commicarpus scandens comes into full bloom from January until April and again from late July until November, and during both

ECOLOGY OF SCOLIIDAE

FIG. 11.—Near Coamo, P. R. Roadside fence covered with tangled growth of *Commicarpus sacandens* in full bloom, a favorite haunt of *Elis haemorrhoidalis*, **F.** (Photo. H. E. Box)

flowering seasons large numbers of fossorial Hymenoptera can always be observed. Where these wasps go to during the non-flowering season of this plant has not yet been ascertained, but it is believed that the flowering of the plant has an influence upon the abundance of the wasps in any given locality.

The other plant whose presence in abundance is intimately connected with that of fossorial wasps is *Kallstroemia maxima* (*yerba de cerdo*), a member of the Zygophyllaceae, with pale yellow flowers reminiscent of the buttercups *Ranunculus* of temperate climes, and whose general growth and habitat are suggestive of the common *verdolaga* (*Portulacca oleracea*, Linn.), with which it may easily be confused by the uninitiated. On the south of Porto Rico the *yerba*

de cerdo occurs in many situations where conditions do not favor the growth of the *verdolaga*, which prefers the *poyal* lands to the sandy spots where the first-named plant abounds. Many of the *callejones* separating canefields at Aguirre are literally carpeted with a thick

ECOLOGY OF SCOLIIDAE

FIG. 12. — Guaimati, near La Romana, Dominican Republic. Broad "*carriles*" with undergrowth of grass; principal nectar-bearing flowers are these of *Paullinia pinnata*, growing over young *guácima* trees, favorite haunt of many species of Scoliidae, especially *Dielis atrata*, F. (Photo, H. E. Box)

growth of this weed (Figs. 9 & 10), and during its flowering season (which appears to be continuous, with an optimum in July and August) thousands of Hymenoptera are attracted by its delicate perfume; among the wasps the Scoliid *Dielis dorsata* is the most

frequent and on sunny mornings thousands of the females of this species may be seen in most places where this plant occurs.

Other plants which have been found attractive to Scoliidae in Porto Rico are the white-flowered mint *Hyptis atrorubens* (Labiateae), the common blue verbena, *Stachytarpheta jamaicensis* (Verbenaceae), and *Mitracarpus portoricensis,* recorded by Mr. Wolcott, to which the writer can add the yellow ironweed or *escoba, Sida carpinifolia* (Malvaceae), a purple-flowered mint, *Leonurus sibiricus* (Labiateae), and *Leucaena glauca* and an un-named spiny-stalked *Mimosa* (Leguminosae). The large moca trees (*Andira inermis,* Urb.), when in bloom, are attractive to bees of various genera, but do not seem to be especially so to the wasps, although *Dielis dorsata* has been noted more than once at their blossoms.

Certain Scoliids, *e. g.,* some species of *Tiphia,* are not anthophilous; their females refresh themselves with the honey-dew secreted by aphids and scales, and hence a difficult problem is presented, for to provide a larger amount of scale or aphid-infested vegetation, though beneficial from the view of tending to encourage *Tiphia,* is in all other directions detrimental to the Island's interests. As an alternative, the writer believes that both the indigenous species of *Tiphia* and any that may be introduced in the future, can be assisted in their propagation by importing into the Island certain species of *Cordia* (Boraginaceae), possessing hair-like glands upon the leaves, which secrete a sweet honey-dew very attractive to Scoliids and other wasps. Several species of *Cordia* occur in Porto Rico, but the writer has not observed any of them to possess the faculty of attracting fossorial Hymenoptera during their non-flowering season, such as occurs with *Cordia aubletii* in British Guiana and *C. interrupta* in Barbados.

The seasonal distribution of the Scoliidae, and the factors governing their relative abundance, are subjects of paramount importance, yet which cannot be discussed owing to the short time that the writer has been able to devote to them. Undoubtedly climatic conditions cause fluctuations in the curve of their abundance, and in the time occupied in their early stages underground, as well as in their geographical and topographical distribution. These and other important considerations must be left over to some future publication.

METHODS OF REARING SCOLIIDAE

Provided reasonable care is taken there should be few difficulties attached to the successful rearing of Scoliids either in small numbers

or in bulk upon a commercial scale; the chief thing to be observed is the correct regulation of the temperature and humidity of the receptacles used; these should be kept as far as possible at a temperature of a few degrees above or below 80° F., and the soil in them kept slightly moist, but not wet. Frequent changes of the soil are necessary, unless sterilized earth is used. To carry out the work upon anything like a large scale, however, insectaries, equipped with incubating departments, would become necessary. No expense should be spared to make the building where rearing work is being carried on as free as possible from ants, silver-fish, and especially mites. We hope the day will come when the sugar-cane properties of Porto Rico (or at least the larger ones) will be provided with field insectaries for breeding parasites, similar to those in use in the Californian citrus-growing regions, where millions of ladybird-beetles (Coccinellidae) are raised annually to combat the scale-insects that would otherwise ruin thousands of dollars' worth of fruit-trees.

Four operations are concerned in the raising of Scoliid wasps: (i) oviposition; (ii) rearing the larvae to maturity; (iii) care of the cocoons; and (iv) mating. Most of the apparatus is such that can be procured at almost any hardware store, but for certain stages of the work the writer uses special boxes and cages. It must be remembered that we have only recently commenced the work of breeding Scoliids at Aguirre, and that probably as time goes on modifications will be made in the process described below:

I. OVIPOSITION

For the smaller species of *Dielis*, and *Elis*, glass fruit jars (Atlas pattern), 5½ inches high by 3⅜ inches top diameter, are used, while for the large *Dielis atrata* jars of similar diameter, but 9½ inches high, are to be recommended. The glass lids and rubber bands are removed from the tops of the jars, which can be covered with removable standard-size lamp-chimneys 3½ inches in diameter at the base; these chimneys conveniently rest upon the rims of the jars, and their tops are covered with muslin or other cloth kept tight by means of rubber bands. The jars are loosely filled with sifted (and sterilized, if possible) soil, to within an inch of the top, and into the surface of the soil is stuck a sprig of some flowering plant upon the leaves of which some diluted honey has been sprinkled. The appearance of this apparatus as at present used at Aguirre is shown in Figs. 13 & 14.

The chimney is removed and a suitable living white-grub placed

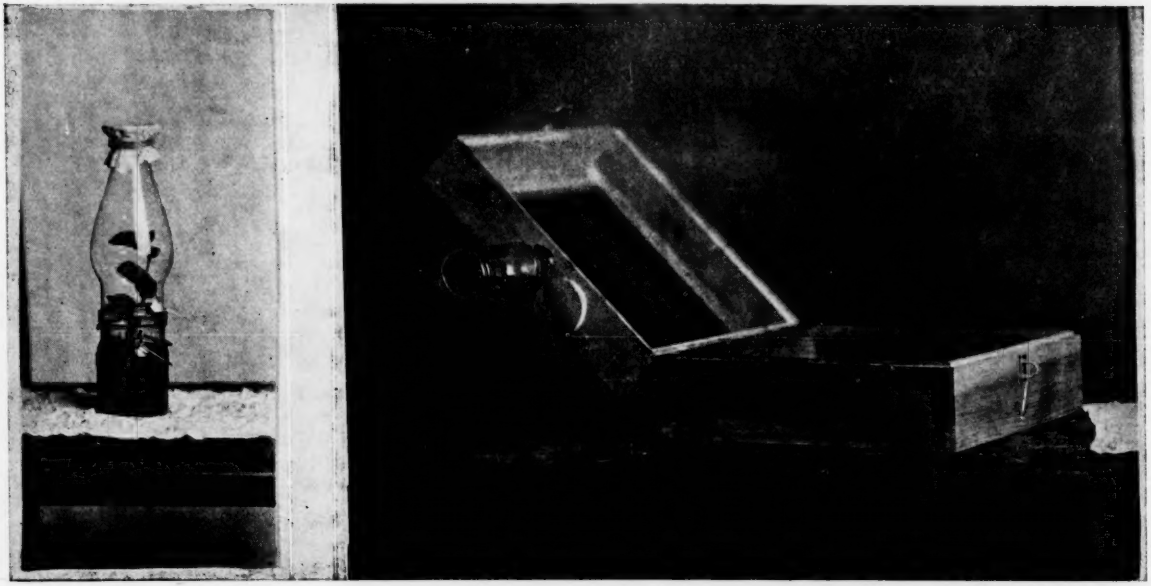
in the soil a few inches below the surface, after which a female wasp is let loose within the chimney, which is rapidly placed over the jar, and the whole ticketed for reference and left for a length of time sufficient for parasitism and oviposition to take place. Generally the wasp drags the grub to the bottom of the jar, where she makes a cell around it, in contact with the side, so that often the grub can be viewed through the glass. When an egg has been deposited, indicated by the wasp coming up into the open air, the soil is gently tilted out of the jar, the wasp having been captured in a small tube, and the paralized grub with the wasp's egg attached removed with forceps, or by means of a long-handled spoon, after which another grub is placed in the soil, the wasp returned, and the chimney replaced, for the process to be repeated. Under properly organized conditions two changes per day may be considered desirable. It often happens that grubs are stung without being oviposited upon by the wasps, when they have to be replaced by fresh living grubs, though in one or two instances the writer has been able to get the wasps to oviposit upon a paralized grub which has been put back into the jar. When such a grub is left on the surface of the soil, the wasps will endeavor to drag it down to the bottom of the jar, often becoming exhausted by so doing; such conditions, being unnatural, are not to be encouraged.

II. REARING THE LARVAE TO MATURITY

For rearing the wasp-larvae the writer has designed a type of box, 15 inches square at the base and 4 inches deep, with hinged lid of the same dimensions, fitting tight by means of flanges. The centre of the lid is cut out for a space 11 inches square to allow of the insertion of copper mosquito wire, thereby providing for aeration. At one side of the lid is a round hole, 2 inches in diameter, which can be closed when necessary, but which, when open, allows the insertion into it of a bottle whose mouth is of a size which enables it to be pushed into the hole more or less tightly (Figs. 13, B & 15). Moulding sand is put into the box to a depth of three inches, and rows of depressions made in the sand while it is still damp, these depressions being of a size suitable for the accommodation of the paralyzed grubs.

When a paralyzed grub with egg attached is located in one of the oviposition jars, it is removed and placed upon its back in one of the depressions in the moulding sand, an indentification number placed immediately above it, and is left until the egg hatches.

FIG. 13.—Apparatus employed in artificially rearing Scoliidae. (Photo. Rodríguez Serra, Ponce)



A B

A—Oviposition jar with lamp-chimney.
B—Box for rearing the larvae and storing the cocoons, with glass bottle inserted into side of lid to trap the adults as they emerge from the cocoons.

Consumption of the grub by the wasp-larva takes place within the shallow depression, and when the wasp-larva is mature, the depression serves as the base of a cell for the formation of the cocoon; without this small device (which the writer gleaned from Dr. Illingworth's paper on similar work done in Queensland) the larvae are unable to form cocoons and perish.*

III. CARE OF THE COCOONS

In large-scale work the cocoons would be left *in situ* as they are formed, but at present they are being removed to another similar type of box. The sand should be quite dry, and the necessary moisture obtained by covering the lid with a double layer of damp cloth, over which a piece of card-board is laid; in such an atmosphere created within the box, the cocoons do very well. As the pupal stage lasts at least one month, it is necessary to constantly watch out for the apperance of moulds or other fungi; when fungi are found the cocoons should immediately be transferred to another box containing fresh sand.

Wasps as they emerge from the cocoons will readily fly into the glass bottle inserted in the side of the lid of the box, being attracted thereto by the light shining through the aperture, the rest of the box being dark.**

IV. MATING

The wasps are transferred from the glass bottles to small wooden cages, 12 inches high upon a 9 by 9 inches base, containing a bunch of nectar-bearing flowers. Mating takes place within these cages, the females being removed twenty-four hours after being put with the

* Since the above was written, the writer has found it safer and very much more convenient to place each paralyzed grub with its attached egg inside a glass tube, two and a half inches long by half an inch in internal diameter, the ends of which are plugged with absorbent cotton. Growth and pupation of the Scoliid larva takes place within the tube without any risk of contamination from neighboring grubs which may be infected with *Metarrhizium* or other fungi, as well as those plagues of the insectary, the Acarina or Mites. The cocoons when properly hardened on the outside are easily removed from the tubes and transferred to storage boxes.—H. E. B.

** A very heavy mortality occurred among the eggs, larvae, and cocoons of a species of Scoliid being reared at Aguirre during 1925, and this was found to be due in large measure to unsuitable temperature. Incubators were improvised by means of enclosing electric-light bulbs in boxes of suitable dimensions, the interior of which maintained a temperature varying little from 80 degrees F. The smaller boxes containing developing larvae and cocoons were stored in these "incubators" and very much better results were obtained than when they were left exposed to the fluctuations of room temperature, which frequently dropped below 70° F. at night. It cannot be said, however, that we have yet found a really satisfactory method of raising Scoliids during the cooler months of the year, and much research will have to be done before this is likely to be obtained.—H. E. B.

males, of which there should be three or four for every female present.

RECORDING DATA

As a basis for all future work it is necessary to keep accurate

TWO VIEWS OF THE TEMPORARY PARASITE LABORATORY, CENTRAL AGUIRRE

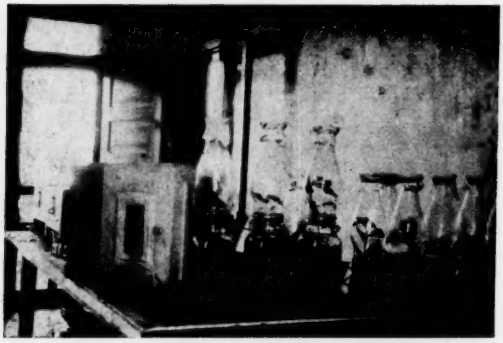


FIG. 14.—Oviposition. Jars. (Photo. H. E. Box)
Right: for the medium-sized *D. trifasciata.*
Left: for the large *Dielis atrata.*
Note Mating Cages behind large jars.

FIG. 15.—Boxes for Rearing the Larvae and Storing the Cocoons. (Photo. H. E. Box)

records of all ovipositions, hatchings, pupations, and emergences.

The system adopted is to give the female wasps of each species an identification number consecutively as they are obtained either

by being collected in the fields or by having emerged in captivity, the former bearing the prefix "O" (original series), while the latter of the first generation have the prefix "I" those of the second generation "II", and so on. The eggs as they laid are also numbered consecutively, the egg numbers being prefixed by the serial and individual numbers of the parent; by this means the ancestry of any particular individual can be traced, and, on the other hand, it is possible to trace the entire progeny of any female.

THE SPECIES OF PORTO RICAN SCOLIIDAE *

Mr. Wolcott, in his "Insectæ Portoricensis", lists the following species of Scoliidae recorded as occurring in Porto Rico:

1. *Elis haemorrhoidalis, Fabricius* (=*E. sexcincta*, F.)
2. *Elis ephippium*, Fabricius
3. *Elis nitida*, Smith (as *Myzine*)
4. *Tiphia argentipes*, Cresson
5. *Tiphia* sp., probably the same as No. 4
6. *Dielis atrata, Fabricius* (as *Campsomeris* and *Scolia*)
7. *Dielis pyrura*, Rohwer (*as Campsomeris*)
8. *Dielis pyrura*, Rohwer (as *Campsomeris*)
9. *Scolia plumipes*, Drury
10. *Dielis maculata*, Drury (as *Campsomeris*) (=*C. druryii*)
11. *Dielis tricincta*, Fabricius (as *Campsomeris*)
12. *Dielis trifasciata*, Fabricius (as *Campsomeris*)

DESCRIPTION AND DISCUSSION OF THE PORTO RICAN SCOLIIDAE

The following account of the Scoliid wasps of Porto Rico is far from complete, but it is considered advisable to place on permanent record the observations that have been made by the writer to date, as well as to summarize in a convenient form what was previously known of these insects; the records are based whenever possible upon the writer's own observations, but where these are not available free use has been made of Mr. Wolcott's invaluable check-list and other publications. Some of the rarer species have not been met with by the writer in Porto Rico, but were found on the Romana properties in the Dominican Republic; observations based upon this Dominican material of the Porto Rican species are included in this discussion for convenience.

* The writer is indebted to Mr. G. E. Bryant, who, while temporarily acting as Director of the Imperial Bureau of Entomology, London, England, very kindly supplied information relating to synonymy among the generic names of the Scoliidae, leading to the adoption of the nomenclature employed throughout this paper. It may be worth mentioning that the species referred to as the genus *Dielis* have hitherto been included among *Campsomeris*, which, it is pointed out, is synonymous with *Scolia*, the latter name taking predominance. The species of West Indian "*Campsomeris*" are properly referrable to *Dielis*.

The descriptions are not to be interpreted as being technical diagnoses of the species, but merely as general aids to their identification.

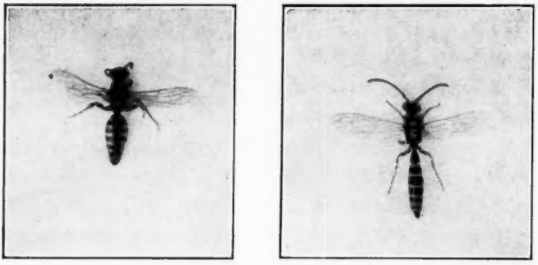
1. *Elis haemorrhoidalis*, Fabricius

(Fig. 16)

DESCRIPTION:

Female—Length 10–12 mm., wing expanse 18–20 mm. Black with several bright yellow marks upon the head and thorax; abdomen with a series of five yellow bands, interrupted dorsally so that there appears to be a black stripe along the back; posterior end of the abdomen red; legs red; wings transparent.

Male—Length 11–14 mm., wing expanse 20–24 mm. Head and thorax with markings somewhat similar to those of the female; abdomen very slender, black with six narrow yellow transverse bands which are *not* interrupted dorsally; posterior end of the abdomen black; legs red; wings transparent.



A B

FIG. 16.—*Elis haemorrhoidalis*, F. **(natural size)**
(Photo. H. L. Dozier)
A—Female B—Male

HOSTS *Phytalus apicalis*, Blanch. (third-instar larvae).

HYPERPARASITE: *Anthrax gorgon*, F. (Bombyliidae).

DISTRIBUTION: Fairly common all over Porto Rico, but inclined to be locally abundant; not known from elsewhere.

FOOD PLANT OF FEMALE: *Commicarpus scandens* ("*pega-pega*").

On the south coast this species occurs abundantly in certain restricted localities, in one of which parasitism was found to amount to 65 per cent of all *Phytalus* grubs during February and March. The males could be seen in hundreds flying over the surface of the ground or resting in clusters upon the leaves and flowering spikes of *bledo* (*Amaranthus* sp.) in the vicinity, while large numbers of the females occurred during the mornings on their food-plant, *Com-*

FIG. 17.—*Elis ephippium*, F. (natural size)

Female at left, male at right
(Del. ad. nat. H. E. Box)

micarpus scandens. Advantage was taken of the abundance of the females of this wasp to collect and transport them to another *hacienda* some thirteen miles eastward, where *Phytalus* grubs were known to be common in certain fields, but where hitherto no signs of the presence of the parasite has been noticed. During February and March 1,200 females were collected and released in the new locality, with the result that on the 3rd of April they had accounted for 7 per cent of the *Phytalus* grubs, while three weeks later parasitism had amounted to 26 per cent. During late May and early in June the parasities were more abundant in their new quarters than in the locality from which they had been taken. At the time of writing (August), owing to the absence of *Phytalus* grubs in numbers, *E. haemorrhoidalis* is comparatively scarce in both regions, nevertheless sufficient has been accomplished to demonstrate the possible results obtainable by transporting parasites from places where they abound to parts where they are scarce or absent. It is planned to make further distributions of *E. haemorrhoidalis* when next it can be found in sufficient numbers to enable collections to be made. The males, it may be of interest to record, are very fond of flying around, and resting upon, the white flowers of the Composite weed *Parthenium hysterophorus*, L., a plant which does not appear to be attractive to the females.

The complete life-cycle was worked out in one instance only, and consequently should not be regarded as typical, as it may not represent the average:

TABLE I

LIFE-CYCLE OF *ELIS HAEMORRHOIDALIS*, F.

Egg. No.	Egg. Laid	Egg. Hatched	Egg. Stage	Larva Spun up	Larva Stage	Adult Emerged		Cocoon Stage	Total, egg to adult.
	Date	Date	Days	Date	Days	Date	Sex	Days	Days
1/1	16.iii	17.iii	15	21.iii	4.5	30,iv	m	41	47

2. *Elis ephippium*, Fabricius

(Colored Plate III, Figure 17)

DESCRIPTION:

Female—Length 15–25 mm., wing expanse 20–30 mm. Entire body black except for the centre of the dorsal part of the thorax, midway between the bases of the wings, where there is a rectangular spot bright red in colour; legs black, wings transparent, slightly smoky towards apex.

Male—Length 18–22 mm., wing expanse 28–34 mm. Very sim-

ilar to the male of *E. haemorrhoidalis*, but larger. Head and thorax with a number of transverse yellow bands, and a pair of short longitudinal bars, on penultimate segments; legs dark yellow; wings transparent yellowish.

HOST: Unknown in Porto Rico.

HYPERPARASITES: Unknown.

DISTRIBUTION: Porto Rico, St Thomas, Antigua. Stated by Wolcott to be rather common during the fall on the north of Porto Rico, around the Río Piedras district.

FOOD-PLANT OF FEMALE: Smyth states that the females occur on the flowers of *Hyptis atrorubens*.

This is one of the Scoliids whose distribution in Porto Rico, so far as is at present known, is confined to the north of the Island, and is one which the writer considers should be bred and tried out upon the south coast. Although a fairly large number of females have been obtained from time to time by the entomologists of the Experiment Stations, nothing appears to be known of the host of this parasite in Porto Rico.

Owing to the fact that *Elis xanthonotus*, Roh., a species so closely resembling *ephippium*, F. as to appear identical except to an expert, attacks and can be reared upon the second-instar larva of *Lachnosterna portoricensis*, there is every reason to believe this beetle to be the host of *ephippium* in Porto Rico.

In Santo Domingo the writer collected two female *Elis* of the same general *facies*, *i. e.*, black with a red mesonotum * on flowers of *Paullinia pinnata*. Both of those insects arrived alive at Aguirre, and one of them oviposited six times upon *L. portoricensis* grubs; the mortality was heavy and only one specimen, a male, was raised from this material. Believing the female to be the same as the Porto Rican *ephippium*, the writer was astonished to find the male quite different from specimens of *ephippium* collected at Río Piedras. The other female from Santo Domingo did not oviposit, though it stung *portoricensis* grubs in the rearing-jars.

The three individuals, a female and its male progeny, and another female (which differed visibly from the first, particularly in the shape of the colored thoracic area and in the presence of a yellow bar posterior to it), were forwarded to Dr. L. O. Howard, who kindly gave them into the hands of Mr. S. A. Rohwer of the United States

* In Mr. Rohwer's original description he states that *xanthonotus* is "Readily distinguishable by its black color and yellow mesoscutum". The mesoscutum in the example collected in Santo Domingo is bright red, a color to which the yellow parts of Hymenoptera frequently change when the specimens are left in cyanide-bottles for any length of time, so it is possible Mr. Rohwer was misled into believing the red color of the mesoscutum in preserved specimens was yellow in life.

National Museum. Mr. Rohwer, in his report, separates the species as follows:

The female with bred male is stated to agree with the type of *xanthonotus*, Roh., which was described in 1915 from one female collected at Río Piedras, Porto Rico, by Mr. T. H. Jones in 1912. This name was later (1920) sunk by Mr. Rohwer as synonymic with *ephippium*, F. Mr. Rhower states in his report that "The synonymy may be correct but inasmuch as there are two species which agree with Fabricius' original description it seems advisable to use the name *xanthonotus* for this form until the type of *ephippium* can be studied." If by any chance this species is found to be identical with the true *ephippium*, a new name will have to be found for the Porto Rican insect whose male is so very distinct, and which is at present known as *ephippium*.

The solitary female from Santo Domingo "differs from *xanthonotus* in the sculpture of the head and pronotum, etc. It may be *ephippium*, but the type must be examined before it can be determined." The writer finds it to differ from females labelled "*Elis ephippium*, F." in the collection of the Insular Experiment Station of Porto Rico.

It seems, therefore, that *Elis xanthonotus* occurs in both Porto Rico and Santo Domingo, and that in each of these countries there exists one other similar species, neither of which do we believe to be common to both islands.

TABLE II

LIFE-CYCLE OF *ELIS XANTHONOTUS*, Roh.

Egg No.	Egg Laid	Egg Hatched	Egg Stage	Larva Spun up	Larva Stage	Adult Emerged		Cocoon Stage	Total, egg to adult
	Date	Date	Days	Date	Days	Date	Sex	Days	Days
1/1	22.vii	24.vii	2	30.vii	6	5.ix	m	37	45

NOTE: This individual was the progeny of a female collected at Guaimati, Dominican Republic, and was reared at Aguirre, Porto Rico, on a 2nd-instar grub of *Lachnosterna portoricensis*.

3. *Elis nitida*, Smith

Unknown to the writer.

A species recorded by Dr. Agustín Stahl in his "Fauna de Puerto Rico" in 1882, which has not been recorded since that date.

This species is also reported from Santo Domingo, Cuba, and Jamaica. Mr. Wolcott informs the writer of recent captures of this species in the vicinity of Port-au-Prince, Haiti.

4. *Tiphia argentipes,* Cresson

Unknown to the writer.

Recorded by H. Dewitz (1881), Dr. Stahl (1882), Dr. J. Gundlach (1894), and Dr. W. H. Ashmead (1900)

Mr. Alex Wetmore records finding *Tiphia* sp. (according to Mr. Wolcott, probably the species under discussion) among the stomach contents of a kingbird, or "*pitirre*" (*Tyranus dominicensis dominicensis,* Gmel.).

T. argentipes is also reported from Cuba and St. Vincent.

5. *Tiphia* sp.

Three males of a *Tiphia,* which, according to Mr. S. A. Rohwer may represent a new species, were found in the Guánica district by Mr. E. H. Barrow in 1921, feeding upon the secretions of a scale, *Pulvinaria psidii,* Mask. on *Rauwolfia nitida.* Another male was subsequently found on cotton at Yauco. At one time it was suspected (on very good evidence, too) that these *Tiphia* might be the progeny of some insects of the same genus brought into Porto Rico during 1913, releases of which were made in the Guánica district.

In Santo Domingo the writer collected two specimens of *Tiphia,* one, a female, on aphid-infested corn in the grounds of the Experiment Station at Santiago, while a male was taken under precisely similar circumstances at La Vega; both of these localities are in the interior of the Island.

The two specimens were examined by Mr. Rohwer, who states the female to be *T. punctata,* Robt., a species known from continental North America ranging from southern Canada to Texas and Louisiana. It has not previously been recorded from the West Indies, so far as the writer knows.

The male from La Vega is stated by Mr. Rohwer to be "the same as has been previously collected by Barrow."

Although there is some evidence that both the male and female *Tiphia* from Santo Domingo are *T. punctata* (in which case the Guánica individuals would also be of this species), there is actually no proof that this is the case, as it was not possible to specifically determine the male sent by the writer to Mr. Rohwer. Definite

information can only be obtained by having males bred from known females available for determination.

If Mr. Barrow's specimens are (as the writer believes them to be) of the widely distributed *T. punctata*, it is not improbable that they are descendants of individuals released in the Guánica region by Mr. Wolcott in 1913–14, for *punctata* was included among the introductions to Porto Rico from the State of Illinois. On the other hand, seeing that *punctata* occurs in Santo Domingo, where it was certainly not introduced, there is no reason why the Guánica *Tiphia* may not have been native to Porto Rico.

6. *Dielis atrata*, Fabricius

(Fig. 18)

DESCRIPTION:

Female—Length 35–50 mm., wing expanse 50–75 mm. Head, body, and legs, entirely black; wings dark orange-yellow at the base and for more than two-thirds of their length; apex of the wings smoky by transmitted light, bright steely blue by reflected light.

Male—Length 28–35 mm., wing expanse 40–45 mm. Color the same as that of the female, except that the orange color of the wings is not so pronounced, and the apices of the wings not quite so dark.

HOST: Not definitely proven in Porto Rico, but undoubtedly the larvae of *Stataegus* titanus and *S. quadrifoveatus*. The former species was readily parasitized in the third instar by *D. atrata* brought in from Santo Domingo.

HYPERPARASITES: Unknown.

DISTRIBUTION: Porto Rico, Santo Domingo, Cuba, Jamaica. Stated by Dr. Gundlach (1894) to be very common in Porto Rico, but, nevertheless, during the last two decades and a quarter only two captures have been made*: a male in a canefield at Aguirre (1913, G. N. Wolcott,) and a female at Lares (1923, F. Seín). The writer found *D. atrata* commonly in some districts of the Romana properties, but it was not seen elsewhere in Santo Domingo. Mr. Wolcott informs the writer that it occurs to some extent in Haiti.

FOOD-PLANTS OF THE FEMALE: In Santo Domingo the wasps of both sexes are attracted to the flowers of *Paullinia pinnata*.

Dielis atrata (also referred to as *Scolia* or *Campsomeris atrata*) is one of the largest of the West Indian Hymenoptera, some of the females having a wing-spread of over three inches. Owing to its

* Since the above was written, the writer has taken two males and two females of *D. atrata* on flowers of *Commicarpus scandens* in one of the Aguirre *haciendas* north of Santa Isabel. The females readily oviposited upon mature grubs of *Stataegus titanus* collected from cane-stools in the same locality.

PLATE IV—PORTO RICAN SCOLIIDAE

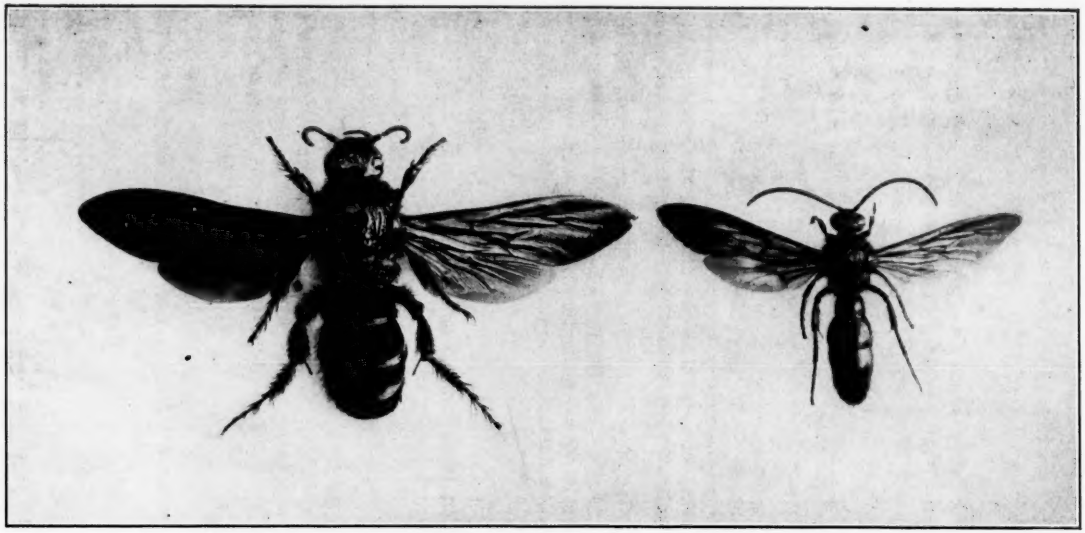


FIG. 18.—*Deilis atrata*, **F. (natural size)** (Photo. Rodríguez Serra, Ponce)
Female at left, male at right

NOTE: The abdomen of the female is considerably longer than appears from the photograph; the example illustrated here has the apical abdominal segments bent downwards, and out of sight.

extreme rarity in Porto Rico during recent years, very little is known of the habits of this species. While in the Dominican Republic in July the writer found *D. atrata* quite common in certain localities near Central Romana in the province of Seiba, and twelve females were collected for shipment to Porto Rico. Only three arrived at Aguirre alive, and these were immediately transferred to jars of soil containing proper food and prey, it being considered that the third-instar grubs of the sugar-cane rhinoceros beetle (*Strataegus titanus*) would serve for the purpose. The wasps commenced to oviposit at once, and eggs were secured from the three individuals, as follows:

Female No. 0–1____23 eggs, between 19–vii and 10–viii (wasp died 10–viii)
Female No. 0–2____12 eggs, between 21–vii and 3–viii (wasp died 5–viii)
Female No. 0–3____23 eggs, between 21–vii and 16–viii (wasp died 18–viii)

Mortality during the egg and larva stages was very high, due to unfavorable conditions, but thirteen cocoons have been obtained, and, provided the sexes are about even, we expect to be able to continue the rearing work upon the emergence of the adults late in September.* Nevertheless, it is proposed to make further importations of *Dielis atrata* from Santo Domingo at some time in the near future, as the species may be reckoned as being very desirable to firmly re-establish upon cane lands in Porto Rico, where, as has already been mentioned, considerable damage is done by rhinoceros beetles and their grubs.

Typical haunts of the adults of this wasp in Santo Domingo are shown in Fig. 12, consisting of broad *carriles* (equivalent to our *callejones*) with a thick undergrowth of grass and weeds interspersed with small *guácima* trees, over which can be found climbing the vine *Paullinia pinnata*, whose flowers are so attractive to the adults The males cluster together upon the leaves and branches of the *guácimas*.

TABLE III

PARTIAL LIFE-CYCLE OF *DIELIS ATRATA*, F.
(Average of twelve specimens)

Egg Stage	Larva Stage
Days	Days
3.5	9.5

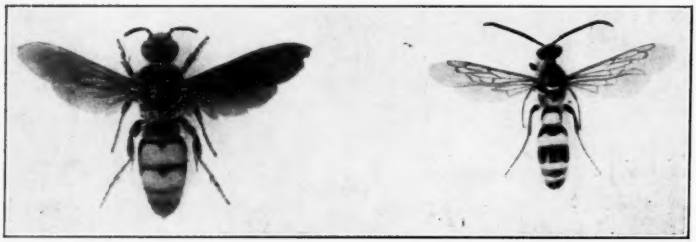
* No adults emerged, as all the pupae became infected with *Isaria* fungus.—H. E. B.

7. *Dielis dorsata*, Fabricius
(Fig. 19)

DESCRIPTION:

Female—Length 20–25 mm., wing expanse 28–35 mm. Head and body black; abdomen with brick-red bars on the second and third segments, each bar of characteristic pattern (Fig. 19, A) legs black; wings almost opaque smocky by transmitted light, bright steely-blue by reflected light.

Male—Length 18–22 mm., wing expanse 25–32 mm. Differs entirely from the female, the species being sexually dimorphic. Body black, covered with a fine greyish pubescense, which appears almost silvery in newly-emerged individuals. There are two curved bars, pale yellow in color, upon the clypeus or face, between the eyes, enclosing a black area; a narrow yellow ring in front of the thorax, just behind the head, and a pair of thicklsh yellow bars at the base of the thorax, the



A B

FIG. 19.—*Dielis dorsata* F. (1¼ times natural size) (Photo, H. L. Dozier)
A—Female B—Male

anterior one being the larger. The abdomen is black, with pale yellow rings upon the first four segments, the rings of characteristic pattern; legs mostly black, but with pale yellow stripes on the inside of each segment; wings transparent with black neuration.

HOST: *Ligyrus tumulosus* (third-instar larvae); occasionally the third-instar larvae of *Lachnosterna portoricensis*, and probably *L. vandinei.*

HYPERPARASITES: *Anthrax lucifer*, F. (Bombyllidae), and an undetermined Dipteron (recorded by Mr. Smyth).

DISTRIBUTION: South America (Brazil, Guiana, etc.), Barbados, and Porto Rico; was not seen in Santo Domingo. In Porto Rico *D. dorsata* has a wide distribution, but would seem to be more abundant on the south coast.

FOOD-PLANTS OF FEMALE: Almost any nectar-bearing flowers, but especially *Kallstroemia maxima, Commicarpus scandens, Sida*

FIG. 20.—*Dielis pyrura*, Roh. (1¼ times nat. size)

Female at left, male at right
(Del. ad. nat. H. E. Box)

carpinifolia, and *Leonurus sibiricus.* Occasionally females are attracted to the flowers of the *moca* (*Andira inermis*), as well as those of *Leucaena glauca.*

Dielis dorsata is one of the commonest wasps, and certainly the commonest Scoliid, in Porto Rico, ocurring almost ubiquitously wherever its host abound. When stable manure containing grubs of *Ligyrus* is applied to canefields, *D. dorsata* can shortly afterwards be seen in hundreds in the vicinity of such fields, retaining its abundance until the last of the grubs has pupated or been parasitized. An instance of the effectiveness of this parasite was observed by the writer on the south coast, where, in a *callejón* between two fields of young cane, *Ligyrus* grubs could be collected in thousands during February, while six weeks later it was difficult to find even one specimen, even in the pupal stage, their place having been taken by the enormous numbers of *Dielis dorsata* later present in the locality.

Occasionally cases of parasitism of *Lachnosterna* by this Scoliid are observed in the canefields, and under artificial conditions *D. dorsata* will readily attack *L. portoricencis* when deprived of its normal host. It is recorded by Mr. Wm. Nowell that in Barbados this wasp acts in a similar way, now and again attacking the Melolonthid *Phytalus smithi* as well as regularly parasitizing the Dynastid *Ligyrus.* In British Guiana *Dielis dorsata* is less common than in either Porto Rico or Barbados, but nevertheless it effects an influence upon the abundance of probably both *Ligyrus ebenus* and *L. gyas* in that country.

It is not improbable, in view of the evidence available, that *D. dorsata* is an accidental introduction to Porto Rico, and in any case should serve to exemplify what can be accomplished with a Scoliid parasite upon white brug control. It is suggested that *D. dorsata* might well be tried out in the United States, where it is believed that it does not occur, as it might prove an efficient parasite for ***Ligyrus rugiceps,*** Lec., a beetle that is sometimes responsible for damage to growing canes in Louisiana.

TABLE IV

LIFE-CYCLE OF *DIELIS DORSATA*, F.

Egg No.	Egg Laid	Egg Hatched	Egg Stage	Larva Spun up	Larva Stage	Adult Emerged		Cocoon Stage	Total, egg to adult
	Date	Date	Days	Date	Days	Date	Sex	Days	Days
2♀2	25.vii	27.vii	2	1.viii	5.5	1.ix	m	31	38.5
2♀3	26.vii	28.vii	2	2.viii	5.5	2.ix	m	31	38.5

8. *Dielis pyrura*, Rohwer

(Color Plate V, Fig. 20)

DESCRIPTION:

Female—Length 22–28 mm., wing expanse 32–40 mm. A very beautiful wasp with the head, thorax, and the end of the abdomen covered with red pubescence; abdomen with brilliant lemon-yellow wavy bands on the first three segments, these bands separated from each other by black patches; legs red, with red spines and pubescence; wings hyaline with red neuration; there is a smoky patch in the region of the apex of the forewing, between which and the base, on the costal region, is a broad orange-colored streak, which blends into the pale yellow of the rest of the wing; the apex of the wing reflects a violet color.

Male—Length 18–22 mm., wing expanse 28–35mm. Colored very similar to the female, but there are yellow bands upon the front of the face, situated obliquely between the eyes, enclosing a black space; the thoracic marks are similar to those of *D. dorsata*, but of a deeper yellow.

HOST: Unknown in Porto Rico. A female brought in from Santo Domingo has been found to parasitize the third-instar grubs of *Lachnosterna portoricensis*.

HYPERPARASITES: Unknown in Porto Rico, but probably the same as those of *D. dorsata*.

DISTRIBUTION: Porto Rico, Santo Domingo and Haiti. In Porto Rico the species is decidedly rare; individual specimens have been taken at Mayagüez (type material of the species), Comerío, and Mona Island. In Santo Domingo the writer found a few specimens at Guaimati. Mr. Wolcott states that it occurs sparsely near Port-au-Prince, Haiti.

FOOD-PLANTS OF FEMALE: Wolcott states that the female occurs on the flowers of *Stachytarpheta* (*Valerianoides*) *jamaicensis*. In Santo Domingo they were found on *Paullinia pinnata*.

The species now under discussion has not been met with by the writer in Porto Rico, but the opportunity was taken of bringing back two females from Santo Domingo. One of these died shortly after its arrival at Aguirre, but the remaining specimen lived forty days in captivity, during which time twelve eggs were deposited upon third-instar larvae of *Lachnosterna portoricensis;* to date only two cocoons have been secured, mortality among the eggs and larvae having been high.

Dielis pyrura should be obtained in quantities from Santo Domingo and artificially reared until its numbers are sufficiently large to enable field releases to be made in Porto Rican canefields.

TABLE V

LIFE-CYCLE OF *DIELIS PYRURA*, Roh.

Egg No.	Egg Laid	Egg Hatched	Egg Stage	Larva Spun up	Larva Stage	Adult Emerged		Cocoon Stage	Total, egg to adult
	Date	Date	Days	Date	Days	Date	Sex	Days	Days
1/1	24.vii	28.vii	3.5	5.viii	8	.....		.....	* .....
1/4	11.viii	15.vii	4	22.viii	7	29.ix	♀	38	49

* Failed to finish pupation.

9. *Scolia plumipes*, Drury

Unknown to the writer.

Recorded by H. Dewitz (1881) and Dr. Gundlach (1894); stated by the latter entomologist to be rare.

10. *Dielis maculata*, Drury

Unknown to the writer.

Recorded by Dr. Ashmead (1900).

11. *Dielis tricinta*, Fabricius

Unknown to the writer.

Recorded by Dr. Stahl (1882), Dr. Gundlach (1894), and Dr. Ashmead (1900). This species is also reported from Santo Domingo, Cuba, Jamaica and Trinidad.

12. *Dielis trifasciata*, Fabricius

(Fig. 21)

DESCRIPTION:

Female—Length 22–25 mm., wing expanse 30–38 mm. Head and body black, with brilliant lemon-yellow bands on first three abdominal segments, these bands separated from each other by black bands bordered with a red line anteriorly where the black and yellow meet; legs black; wings yellowish by transmitted light, with a smoky patch at apex of fore-wings, reflecting purplish; neuration reddish.

Male—Length 18–25 mm., wing expanse 25–32 mm. Body black, covered with dark grayish pubescence. There is a strong similarity between the male of this species and that of *D. dorsata*, but the clypeus is entire yellow, and the abdominal rings are different in shape; the last ring is interrupted dorsally. The yellow markings are darker in tint than those of the male *D. dorsata*, and the wing neuration is reddish rather than black.

HOST: Hitherto unknown in Porto Rico. The writer has found that this wasp normally attacks *Lachnosterna portoricensis*, and in all probability *L. vandinei* is also parasitized by it.

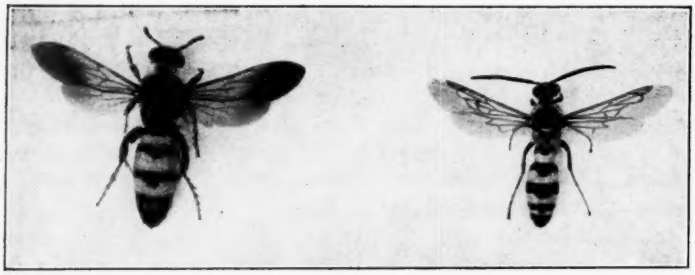
HYPERPARASITES: Unknown in Porto Rico, but probably the same as those of *D. dorsata*.

DISTRIBUTION: Porto Rico, Santo Domingo, Haiti, Cuba and Jamaica. Stated to be not uncommon on the north of Porto Rico, but until recently has not been met with on the south coast; where it has now been found in one restricted locality near Salinas. A few individuals were seen at Guaimati in Santo Domingo. Mr. Wolcott says it is "common" in Haiti.

FOODPLANT OF FEMALES: In Porto Rico, *Kallstroemia maxima* and *Sida carpinifolia*. In Santo Domingo, *Paullinia pinnata*.

On the 6th of June, while watching thousands of the females of the common *Dielis dorsata* flying around patches of *yerba de cerdo* (*K. maxima*) in a *callejón* in one of the Aguirre *haciendas* the writer collected a few individuals which later were identified as

PORTO RICAN SCOLIIDAE



A B

FIG. 21.—*Dielis trifasciata*, **F. (1¼ times natural size)** **(Photo, H. L. Dozier)**
A—Female B—Male

the species now under discussion. Search was continued and visits made subsequently and to date eighteen of these wasps have been secured from the one locality. Although similar places elsewhere have been carefully wached, *D. trifasciata* has not been met with outside an area of less than five acres. It may be worth mentioning that, although four was the maximum number of females of *D. trifasciata* collected on any one occasion, several thousand of the common *D. dorsata* could have been netted had they been required.

The female wasps were collected alive and brought to the laboratory, where they were put into jars with an assortment of white grubs of different stages of *Lachnosterna* and *Ligyrus*, as well as some small *Strataegus*. The two latter types of grubs were absolutely

ignored, nor has the writer since been able to get *D. trifasciata* to parasitize either *Ligyrus* or *Strataegus*. The females, however, readily stung the mature third-instar grubs of *Lachnosterna portoricensis*, and laid eggs upon them, thereby constituting the first known instance of parasitism of a Porto Rican *Lachnosterna* by a native Scoliid wasp.

At first the best results were not obtained, the wasps dying after having laid a few eggs, but, with the improved technique already detailed, the wasps were kept alive for a considerable length of time, depositing eggs upon cane-grubs daily. From the original material four generations have been reared upon cane-grubs, but owing to a series of accidents, the work of rearing this species has not progressed as well as we would have desired. To the end of 1925, that is, within a period of six months, 304 individuals (213 males, 91 females) have been raised from the original fourteen specimens, the latest examples being the third filial generation. The maximum number of eggs obtained from one female was fifty-five (this individual lived 63 days in captivity), the average number being 17 eggs for every female wasp. Some females produced all male progeny, and it was thought that this was due to these having developed parthenogenically; to confirm this, two females, kept away from males, laid eggs which almost invariable produced males, though in two instances female progeny were obtained from unfertilized parents; the female progeny were quite healthy and oviposited normally whether they had been fertilized by males or not. Having had such a large number of these Scoliids on hand for a fairly long period, the writer can record data based upon observations on the effect of temperature on their development:

TABLE VI

LIFE-CYCLE OF *DIELIS TRIFASCIATA*, F.

Period	Temperature			Egg Stage	Larva Stage	Pupa Stage	Total, egg to adult
	Daily Mean	Max.	Min.	Days	Days	Days	Days
June–July	80.60	89	70	2.5	6.5	35	44
August–September	81.28	89	72	2.5	6.5	33	42
November	78.80	86	67	3.0	7.0	42	52

The mortality in all stages increased as the nights grew cooler, so that in order to save the race from dying in captivity artificial heating to be resorted to (see foot-note on page 83). In addition large numbers of eggs and larvae died through attacks of fungi and

bacteria. A release of twelve females, all proven to be in egg-laying condition, was made in one *hacienda* in December, in a situation favorable for their establishment. The number is small, but it may be that they will continue to breed, as cane-grubs were plentiful in the fields around the part where the releases were made.

All the evidence points to *D. trifasciata* holding the status exemplified in Diagram B of Plate I, but the writer believes there should be little difficulty in producing the effect illustrated in Diagram C, if every facility is provided to aid this end.

One great difficulty which may be encountered in breeding *Dielis trifasciata* and the other Scoliids is that of obtaining a supply of the right sort of grubs during the season of the minimum abundance of the latter in the fields; this season is June and July in the case of third-instar *Lachnosterna* (see Plate III). Although with diligent search a fair number of suitable grubs can be obtained, it is not wise to rely on this method where large numbers of grubs are daily used in propagating the wasps. It seems that if during the end of April and during May, several thousand of grubs are collected, these can be stored at low temperatures (about 45° F. being suggested) either in a proper cooling plant or a good ice-chest, under which conditions the growth of the grubs is suspended until they are restored to normal temperatures a few days before being required for use.

INTRODUCING PARASITES FROM ABROAD

This is not a new idea in Porto Rico, and a most excellent summary of all that has been done in the direction of attempting the control of the sugar-cane pests of Porto Rico by means of introduced parasites was written by Mr. Wolcott and published in this Journal in January, 1922. Nevertheless, it is felt that the present paper would be incomplete without a brief *resumé* of what was accomplished along these lines.

Although great success followed the importation of the Australian lady-bird beetle (*Cryptolaemus montrouzieri*, Muls.) from North America, to combat scale-insects and mealy-bugs (Coccidae) in Porto Rico, the beetles having become firmly established and widely distributed in the Island, the same cannot be said of the introductions that were made of Scoliid wasps from the United States, due, in the writer's opinion, to an injudicious selection of the country whence the parasites were obtained.

During the period 1911 to 1913 Mr. C. E. Hood, and later, Mr.

Wolcott, was engaged by the Experiment Station at Río Piedras to arrange for the collection of large numbers of *Tiphia inornata*, Say, *T. punctata*, Robt., and other species of the same genus that exert a marked control over *Lachnosterna* in Illinois and other States. The material was collected in the form of cocoons and shipped to Porto Rico, some in cold storage, other at normal temperatures by first-class mail. At first very few adults were secured, but later, when improvements had been made in the methods of handling the insects during transit and after arrival in Porto Rico, good percentages of emergence were obtained. The wasps were tried out upon various white-grubs and, although in one or two instances they stung the grubs and oviposited upon them, no cases were recorded where one of the imported species of wasp had been reared to maturity upon a Porto Rican grub. In addition to attempting to rear the wasps artificially upon cane-grubs in captivity, several hundreds of adult *Tiphia* were released in some grub-infested fields on the south coast. It cannot be said definitely that these wasps have entirely failed to become established in Porto Rico, but it is certain that they have not increased to such an extent as to make their presence felt today.

While it is quite possible success might follow introductions of white-grub parasites from North America, the writer considers it far more probable that such would be obtained with parasites from neighbouring West Indian islands and from the mainland of South America, where the necessary conditions approach closer to those of porto Rico, and it seems likely that parasites from these countries stand a better chance of becoming acclimatized in Porto Rico than species native to temperate regions, though this does not necessarily apply to all parasites.

Through the enterprise and interest of the Central Aguirre Sugar Company the writer has already been able to demonstrate that there occur in Santo Domingo several Scoliids (*Dielis atrata, D. pyrura* and *Elis xanthonotus*) which are so rare in Porto Rico that their re-establishment and distribution in this Island is desirable. In addition to these, other parasites were found in Santo Domingo during the writer's short visit in July, in numbers insufficient to make shipments. It is very probable that a more extended survey of other parts of Santo Domingo as well as of those localities already visited by the writer in that country, would reveal the existence of other forms of parasites likely to prove beneficial to Porto Rico, as

well as a greater abundance of those already found there in small numbers.

A glance at Appendix II at the end of this paper will serve to show what a field remains in this line of work; the writer considers that Cuba, Jamaica, Trinidad and British Guiana are especially worthy of attention in respect of the species of Scoliids *known* to occur there, and there can be little doubt that an entomologist searching for these insects would find forms not yet described and catalogued. In addition to the countries mentioned above, there are others of the West Indian islands which should be taken into consideration, as well as Columbia and Venezuela on the mainland of South America.

Mention has already been made of *Tiphia parallela*, Sm., which aids in keeping down the numbers of the Melolonthid *Phytalus smithi* Arrow, in Barbados. This Scoliid has a variety of hosts, although in Barbados no Lamellicorn other than *P. smithi* is known to be attacked by it. In Antigua it attacks *Lachnosterna antiguae*, Arrow, a species almost identical in size both in the adult and larval state with *P. smithi* of Barbados, and *L. guanicana* and *L. citri* of Porto Rico. In British Guiana *Tiphia parallela* is not known to attack Melolonthids, but the writer has found cases of parasitism of Dynastids of the genus *Dyscinetus* by it in that country.

In reference to an attempt that was made to introduce *T. parallela* into Porto Rico, Mr. Wolcott states:

"One hundred cocoons were sent (from Barbados) in April, 1913, arriving a month later, but only ten adults emerged. No special arrangements had been made for attempting to have these breed on the grubs of *Phytalus insularis*, Smyth (*apicalis*, Blanch.), the most nearly related (?) Porto Rican species of grub, and the females did not oviposit on the larger *Lachnosterna* grubs.*"

In spite of the negative results recorded by Mr. Wolcott, the writer thinks that *Tiphia parallela* should be given another trial upon Porto Rican white-grubs, especially those of *Lachnosterna*

* I consider both *Lachnosterna guanicana* and *L. citri* to be closer relatives of the Barbadian *L.* (*Phytalus*) *smithi* than *L.* (*P.*) *apicalis* in spite of the fact that the adults of the two latter species have certain minor features in common that some writers rank as generic differences. As it is the larval stage of these beetles that is selected by the Scoliid parasite as food for its progeny, I fail to see that it matters very much that the presence or absence of a certain detail in the structure of the adult form (in this instance a cleft claw in the male sex) exists, for such must be unknown to the wasp, which is familiar only with the subterranean larva, and which cannot have any idea of what the ultimate development of the larva would be if it left it unstung. There are, to my knowledge, no characters present in the larvae of the so-called *Phytalus* which separate that genus from *Lachnosterna*.—H. E. B.

(See second footnote on page 51.)

guanicana and *L. citri*, and suggests that the introduction be made from British Guiana rather than from Brabados, as they can reach this Island in less than ten days by monthly sailings of the Dutch Royal Mail boats from Georgetown, Demerara, which connect with the "Red D" line at La Guayra, Venezuela. Advantage could then be taken of bringing in several other desirable parasites which occur in British Guiana but not in Barbados, viz., certain Braconidae which prey upon moth borers (*Diatraea saccharalis*, F.).

It may be of interest to record that in the summer of 1924 a consignment of adult females of *Scolia manilae*, Ashm. were brought into Porto Rico from Hawaii, by Mr. Norman Kay, of the Central Aguirre Sugar Company. They had been introduced into Hawaii some years previously from the Philippine Islands to combat *Anomala orientalis*, a sugar-cane white grub. The writer is not aware that any detailed experiments were carried out with the wasps with grubs in captivity, but about a hundred of them were released in a grub-infested region on one of the Aguirre *haciendas*, where it is possible they may breed.

In addition to the Scoliidae there are other types of parasites which would be met with during the search for the wasps, and among these are flies which attack both the larvae and adults of the Lamellicornia. Mr. Wolcott has informed the writer of the existence in Haiti of a Tachinid fly, *Ptilodexia harpasa*, Walk, which parasitizes the larvae of *Lachnosterna hogardi*, Blanchard, a beetle very closely related to *L. portoricensis* and *L. vandinei*.

An account of *Ptilodexia harpasa* is given by Dr. J. J. Davis in his "Contributions to a Knowledge of the Natural Enemies of *Phyllophaga*" (Illinois State Natural History Survey, Bulletin, Vol. XIII, Art. V, pp. 82–84, 1919). Dr. Davis remarks that "This fly, first recorded as a white-grub parasite under the name *tibialis*, has a wide distribution, occurring, according to published records, in Nova Scotia and Ontario, Can.; and in New Hampshire, New Jersey, Minnesota, Texas and New Mexico." This parasite, then, has a range extending from Southern Canada to Haiti in the Greater Antilles. It seems quite logical to suppose that an insect which exists under such a wide range of climatic conditions, and which works upon many different species of *Lachnosterna*, including both temperate and tropical species, would be easily adaptable to Porto Rican conditions. The writer believes that *Pt. harpasa* is the most likely of all foreign Diptera to become established in this Island, and hopes to attempt its introduction from Haiti at some time in the future.

CONCLUSION

The writer makes no claim that the present paper is a complete treatise upon the subjects dealt with. Many aspects deserving of deeper consideration have, of necessity, been but briefly touched upon, and much yet remains to be elucidated before we can tell what are the possibilities of the line of control here suggested and advocated as being adopted against one of most serious pests of Porto Rico's major crop.

It is hoped, nevertheless, that the present effort may serve to summarise in a general way and in a convenient form what is known of the Porto Rican Cane-grubs and their natural enemies, particularly the Scoliid wasps, and that this paper may prove of some use to future workers in this most interesting and promising line of inquiry and to those engaged in similar problems elsewhere.

The failure to obtain immediate results with the breeding of native and the introduction of foreign parasites should not discourage further attempts from being made, but should serve to stimulate interest until the right parasites have been found, as they inevitably will be if the work is started and continued in an intelligent and determined manner. It is most improbable that the cane-grubs of Porto Rico can be controlled by any one species of parasites, the ideal being to have parasites for each stage of their existence. A well-organized campaign, under good administration and with no lack of funds, should produce results within a few years sufficient to defray all expenses and leave a substantial balance in the pockets of the planters.

The entire cost of establishing properly equipped laboratories on the north and south of Porto Rico, together with a good library and all other necessities at whichever was made headquarters, as well as all travelling expenses in connection with the search for parasites abroad and at home, could be borne by a tax of 25 cents for every acre under cane cultivation the first year, and considerably less during subsequent years.

The sugar industry of Porto Rico loses not less than *three million dollars every year through the ravages of stalk-borers*, and to this must be added the loss due to white-grubs and weevil root-borer, so that *five million dollars would not be a too high estimate of the Island's annual loss through sugar-cane pests*. Many prominent sugar companies have been known to install outfits and processes in the mill at considerable cost, to increase the sugar output by about

0.1 per cent or even less; and frequently these are done as a speculation. Surely, then, some similar investment might be made in the *field* (for, after all, the raw product—sugar cane—is the basis of the entire industry) which would probably yield a bigger percentage of gain at less cost in the long run.

ACKNOWLEDGEMENTS

The kindness of Mr. C. L. Carpenter, Vice-President and General Manager, Central Aguirre Sugar Company, in giving permission to record in this paper the data and observations secured by the writer since he has been associated with this Company, is here acknowledged with many thanks.

It is desired to acknowledged the courtesy of Dr. Melville T. Cook, Chief of the Division of Botany and Pathology of the Insular Experiment Station of Porto Rico, in supplying the writer with several plant names, without which certain sections of this paper would have been incomplete.

Dr. H. L. Dozier, until recently Chief of the Division of Entomology of the same institution, very kindly prepared the photographs which are reproduced as Figs. 6, A and B; 7, A; 16, A and B; 19, A and B, and 21, A and B.

To the Administrator of Central Romana, Inc., Romana, R. D., the writer is indebted for many courtesies extended to him during a week's stay on their properties during July, 1925, and for providing every facility towards furthering the work upon which he was engaged.

Due credit and the writer's thanks should be given to Mr. D. M. Wilson, of the Central Aguirre Sugar Company, for having assisted by executing the diagrams on Plates I and III.

This paper would be incomplete without a word of appreciation to the Department of Agriculture of Porto Rico, for publishing this article in its very excellent Journal, and to Mr. F. A. López Domínguez, Secretary of the Sugar Technologists' Association of Porto Rico, for having recommended its acceptance.

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APPENDIX I

(NOTE.—In the following, an asterisk (*) signifies that the Scoliid is not actually known to parasitize the grubs under field conditions, but has been found to do so experimentally.)

A. Porto Rican Cane-grubs and their Scoliid Parasites, Where Known.

Lachnosterna portoricensis, Sm.

Parasites:

Dielis trifasciata, F.

Dielis dorsata, F.

* *Dielis pyrura*, Roh.

* *Elis xanthonotus*, Roh.

Lachnosterna vandinei, Sm.

Parasites:

Unknown, probably the same as above.

Lachnosterna guanicana, Sm.

Parasites:

Unknown.

Phytalus apicalis, Blanch.

Parasite:

Elis haemorrhoidalis, F.

Strataegus titanus, F.

Parasite:

* *Dielis atrata*, F.

Ligyrus tumulosus, Burm.

Parasite:

Dielis dorsata, F.

B. Porto Rican Scoliid Wasps and their Hosts, Where Known.

Elis haemorrhoidalis, F.

Host:

Phytalus apicalis, Blach.

Elis xanthonotus, Roh.

Host:

* *Lachnosterna portoricensis*, Sm.

Dielis atrata, F.

Host:

* *Strataegus titanus*, F.

Dielis dorsata, F.

Hosts:

Ligyrus tumulosus, Burm.

Lachnosterna portoricensis, Sm.

Dielis pyrura, Roh.

Host:

* *Lachnosterna portoricensis*, Sm.

Dielis trifasciata, F.

Host:

Lachnosterna portoricensis, Sm.

Appendix II

LIST OF THE SCOLIIDAE OF THE WEST INDIES AND BRITISH GUIANA

The writer is greatly indebted to the Imperial Bureau of Entomology, London, England, for supplying the names of the majority of the species listed below, these being represented by specimens in the collections of the British Museum (Natural History), whence the names were obtained. The list is as complete as the writer is able to make it.

Elis haemorrhoidalis, F.—Porto Rico.

E. ephippium, F.—Porto Rico, Santo Domingo, Antigua, St. Thomas.

E. nitida, Sm.—Porto Rico, Santo Domingo, Haiti, Cuba, Jamaica.
E. bodkini, Turn.—Demerara.
E. flavopicta, Sm.—British Guiana.
E. xanthonotus, Roh. (? syn. *ephippium*, F.)—Porto Rico, Santo Domingo.
E. sp. incert. (undetermined)—Santo Domingo.
Pterombus williamsi, Turn.—Demerara.
Tiphia cameroni, D. T., var.—Grenada.
T. Nitida, Sm.—Jamaica, St. Vincent.
T. argentipes, Cress.—Porto Rico, Cuba, St. Vincent.
T. parallela, Sm.—Barbados, Antigua, British Guiana.
T. punctata, Robt.—Santo Domingo.
Scolia (Discolia) guttata, Burm.—Trinidad.
S. plumipes, Dru.—Porto Rico.
Dielis atrata, F.—Porto Rico, Santo Domingo, Cuba, Jamaica.
D. peregrina, Lep.—Dominica, Tobago.
D. pyrura, Roh.—Porto Rico, Santo Domingo, Haiti.
D. costalis, Lep.—British Guiana.
D. trifasciata, F.—Porto Rico, Santo Domingo, Haiti, Cuba, Jamaica.
D. maculata, Dru.—Porto Rico.
D. tricincta, F.—Porto Rico, Santo Domingo, Cuba, Jamaica.
D. tricincta, F., var.—Trinidad.
D. dorsata, F.—Porto Rico, Barbados, British Guiana.

AN OUTBREAK OF THE RED-STRIPED SUGAR-CANE SCALE

By H. L. Dozier, Chief Entomologist, Insular Experiment Station

One of the most interesting occurrences of the past year was the serious outbreak of a scale insect on sugar cane near Arecibo, something heretofore unknown to have occurred on the Island. This scale, upon study, was found to be *Pulvinaria iceryi* Guérin, a species of which six individuals were reported on leaves of sugar cane at Cayey and Trujillo Alto. It was also reported by Smyth as being abundant in 1919 on his cane grown in the greenhouse where possibly it was protected from its natural enemies. Smyth also reported an apparent 6.6 per cent success in transmitting mosaic with this insect, but his experiments need repeating under better control conditions for substantiation. In addition to Porto Rico, the species has been recorded from British Guiana, Mauritius, and the Reunion Islands. The U. S. Bureau of Entomology has received specimens of this species from the southern part of Georgia (U. S. A.) on sugar cane on several occasions.

It seems rather surprising that this species, after being so long present on the Island, should now suddenly show up in epidemic form. The only theory the writer can advance is that the species which has heretofore been held in check by its parasites was at last enabled to gain the upper hand by a sudden upset in the "balance of nature". This theory is upheld by a study of the internal hymenopterous parasites attacking this species during the outbreak.

THE RED-STRIPED SUGAR-CANE SCALE
(*Pulvinaria iceryi* Guérin = *elongata* Newstead.)

On May 27th, 1925, a trip was made by the writer to Arecibo to investigate a reported oubreak of a scale insect attacking sugar cane. It was found that an unfamiliar scale had attacked a block of forty-five *cuerdas* of young Rayada cane on the farm of Sr. Juan Santos, a colono of the Central Cambalache, about six kilometers from Arecibo on the main highway towards Mayagüez. This insect had been first noticed by Señor José Oliver the latter part of April in a piece of first-ratoon cane, three months after cutting. At that time an average of about one hundred female scales were found to the stool over an area of about five *cuerdas*. This cane had been cut

FIG. 1.—The Red-striped Sugar-cane scale *Pulvinaria iceryi* Guérin = *elongata*, Newstand, on sugar-cane leaves. About natural size. (Dozier)

the first of February and was attacked as it ratooned. The cut cane from this field had yielded better than thirty-five tons per *cuerda* average over the forty-five *cuerdas*. By the 7th of April the insect was found over the entire forty-five *cuerdas*. This entire field was then sprayed by the owner, using the old kerosene oil emulsion formula, one part of the stock to ten of water, and applied with a hand sprayer, about thirty stock gallons being used on this application. The cane foliage was not burned and apparently the application gave some good results.

On the day that the Entomologist inspected this field it appeared distinctly yellow in comparison with the other fields adjacent and in certain areas a large number of the older leaves were dead and dying and fairly well infested with the adult mother scales, beneath which were found large numbers of eggs and numerous newly hatched young. The young larvae were very abundant, settling on the new foliage, and giving promise of more serious damage later. For the three months previous to this time no rain had fallen in that section and this sudden outbreak might have been connected in some way with this extremely dry period.

Again, on June 26th, the writer made a survey of conditions and found that the insect was continuing its damage and in about as abundant numbers as before. At this time the adult females of what was probably the third generation were very abundant and newly hatched crawlers were infesting the new foliage. A strip of about four *cuerdas* of this field was almost a complete loss and active spray measures were being taken against the remainder.

DESCRIPTION AND LIFE HISTORY

The full-grown female scale is very much elongated, measuring 6.50 mm. in length and 2.50 mm. at its greatest width, and although rather flat as a whole is distinctly raised or convex with the surface entirely smooth. It is of a testaceous-yellow color with two rather narrow but well-separated, distinct reddish stripes running almost parallel for most of the body length. These two stripes make their appearance early in the life of the scale, being more or less distinct in the second instar larva and becoming more conspicuous and prominent as the scale matures. These two reddish stripes serve as a ready means of identification and distinguish it from all of the other scales known in Porto Rico. At times the sides of the full-grown scale have a more or less diffusion of reddish vein-like markings outward from the two median longitudinal stripes. After young

are produced these two reddish lines break up into rather faint irregular brownish markings, leaving the scale covering for the most part a testaceous-yellow in color.

FIG. 2.—The Red-Striped Sugar-cane Scale, *Pulvinaria iceryi* Guérin = *elongata* Newstand, on Sugar-cane leaves. About 2 times natural size. (Dozier)

The full-grown and mature female forms a cottony or mealy excretion beneath the scale covering which together with the sugar-cane leaf forms an ovisac and serves as a protection in which the eggs are deposited and where the young are protected after hatching

until they issue out from under the mother scale covering. The eggs are elongate-elliptical in shape, about twice as long as wide at the greatest width, measuring 0.416 mm. in length by 0.224 mm. width, and are of a pale dirty white color. Over one hundred eggs were counted beneath one scale.

The male scale of this species is still unknown although a careful search has been made and much material put up in emergence boxes. In fact it seems that this species must reproduce itself parthenogenetically, that is, without the necessity of being first fertilized by the male.

The newly hatched larva or "crawler" is a testaceous-yellow in color, elongate-oval in outline, measuring 0.528 mm. in length by 0.208 mm. width, with a pair of antennæ or feeler and a pair of long filaments projecting from its hind end. The feet are well developed and the larvæ of most of the stages are very active and frequently change their feeding position on the leaf. In the last instar, however, the full-grown scale is stationary. The newly hatched crawlers react very positively to light and their favorite settling place is along the leaf in the lengthwise depressions and in most cases on the underside of the leaves. Very rarely do they settle and feed along the stalk of the plant.

NATURAL ENEMIES

Adults and young of the ladybird beetle, *Cryptolaemus montrouzieri*, were abundant over the field feeding on the scales of various sizes and many were noticed feeding beneath the adult female scales where they had pushed them up off of the leaf. This beetle was imported from California into Porto Rico by Van Dine in 1911, bred in numbers and turned loose at various points on the Island, and is now after many years proving itself a very beneficial insect, attacking many species of scale insects here.

Material of this scale was placed in parasite-rearing boxes at the time of the first investigation with the result that three species of hymenopterous parasites were reared, a primary parasite, *Aphycus flavus* How; a secondary parasite upon this species, evidently *Cheiloneurus pulvinariae* Dozier; and a few spesimens of a coccophagine, *Aneristus ceroplastæ* How. Later, from more material collected in July the most abundant parasite reared was *Aneristus ceroplastæ* and it was proved by dissecting the adult female scales that this was a primary parasite. In examining parasitized scales some were found with as high as seven and eight emergence holes in them. Out of

275 scales examined on July 10th, 71 were found parasitized, or only 28.7 per cent. With the first batch of material the *Cheiloneurus* was far more abundant than either of the primary parasites, a fact that probably accounts for the rapid rise and spread of the scale without effective natural control.

The following descriptions and drawings are given to enable ready identification of the species of parasites concerned.

Aphycus (*Euaphycus*) *flavus* How.

The writer is indebted to Mr. P. H. Timberlake who, in making the identification of this species, states that although the type of *flavus* has apparently been lost, these specimens agree with what has gone in literature in past years as typical *flavus*.

Female: The frontovertex is about twice as long as wide; the ocelli placed in an acute-angled triangle, the posterior pair close to the margin of the eyes. Antennae inserted near the mouth. Antennal scape flattened and narrow, four times as long as wide at greatest width near the middle, pedicel as long as the first three funicle joints combined; first four funicle joint subequal in length and breadth, the fifth slightly longer and the sixth distinctly longer; fifth and sixth increasing in width so that the sixth is nearly twice as wide as the first joint; club three-jointed, a little wider than the last funicle joint and nearly as long as the last five funicle joints combined. Forewings typical with the oblique hairless streak widened and interrupted below. Hind wings short, the marginal hairs relatively long. Abdomen shorter than the thorax and of about the same width.

General color of upper surface of body an orange yellow, the legs and underpart a paler yellow. Pronotum pale yellow with a fuscous dot on each corner. Antennae yellow, a longitudinal streak or spot on the upper margin of outer surface of the scape towards its apex, the base of pedicel, the first three funicle joints, and the basal half of club, fuscous; the club a yellowish-white in apical half. Legs a uniform pale yellowish, the tarsal claws blackish. Wings hyaline with the veins yellowish.

Length, exclusive of ovipositor, 0.70–1.20 mm.

Male: Similar in coloration to the female except that the metanotum, propodeum and dorsum of abdomen, especially towards apex, are embrowned. Antennae also similar in structure except that the joints all increase in width successively, the club is not three-jointed as in female; the entire flagellum is uniformly dusky.

Length, 0.640–0.840 mm.

Reared in abundant numbers as a primary parasite from *Pulvi-*

naria iceryi on sugar cane at Arecibo, P. R., during May and July, 1925. *Aphycus flavus* has been recorded by various workers as being reared from *Toumayella liriodendri, Tachardia* sp., *Pulvinaria pyriformis, Coccus hesperidum, Chrysomphalus dictyospermi, Aspidiotus hederae,* and *Saissetia oleae.*

Cheiloneurus pulvinariae n. sp.

In the female sex this species resembles most closely *C. inimicus* Compere, but is distinguished by its distinctly smaller size, its lack of a black line on the ventral margin of scape, by having no metallic color on propodeum, and difference in wing venation. The male is

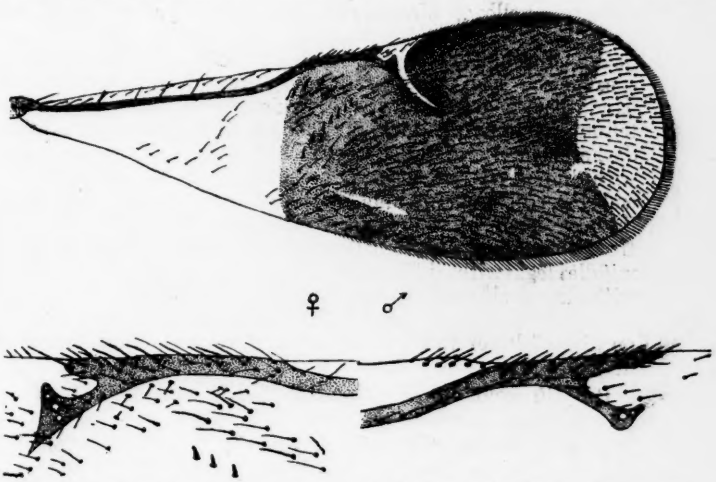

FIG. 3.—*Cheiloneurus pulvinariae* n. sp. **Above, wing of female. Below, venation of forewing of male and female, much enlarged.** (Dozier)

more easily distinguished by having the eyes hairy, and the first funicle joint much longer and with more hair.

Female: Head about one and one-half times wider than long; ocelli arranged in an acutely-angled triangle. Antennal scape slightly expanded below, nearly three times as long as widest width; pedicel triangular, as long as the first two funicle joints combined; funicle joints gradually widen so that the sixth is almost twice as wide as the first; first four joints of funicle about equal in length, the sixth a fourth longer than the fifth. Club three-jointed, oblongate, slightly wider than the scape and about the same length. Mesothoracic scutum about twice as wide as long. Scutellum only slightly wider

than long with the characteristic tuft of black bristles. Pronotum and mesoscutum very finely reticulated, with numerous setigerous punctures, the punctures of the silvered area being larger and elongate; mesoscutum set with eight strong blackish hairs on hind margin; the scutellum is more distinctly and coarsely reticulated. Abdomen about same length as the thorax, with ovipositor sheath slightly exserted. Wing with characteristic embrowning and venation as in Fig. 5.

General color yellowish-orange. Eyes dark. Antennal scape soiled yellowish with the margins slightly embrowned; the pedicel and first three funicle joints more or less distinctly fuscous, varying greatly in slide-mounted material; hairs of the first three joints darker and more prominent than those of the other funicle joints; fourth, fifth and sixth joints a testaceous-yellow. Mesoscutum testaceous yellow with two more or less distinct longitudinal, more orange-colored stripes passing through its length onto the scutellum, in slide-mounted specimens. The posterior third is crossed by a broad dark band that is overlain with an iridescent silvery sheen. Scutellum, metanotum, and propodeum yellowish with slightly darker color than the mesoscutum. Abdomen dirty yellowish with the basal segments and the apex of the last segment embrowned. Femora and tibiæ testaceous-yellow, with varying degree of fuscous markings, forelegs with only slight infuscation along the dorsal margin of femora towards apex; middle legs with infuscation dorsally near knee; hind legs with dorsal sides of femora infuscated, the tibiæ with a more or less distinct band across width on upper third and a blotch on disc of lower third, fuscous; all tarsi testaceous, the claws dusky.

Length, exclusive of ovipositor, 1–1.10 mm.

Male: Antenae entirely different from those of female: scape long and slender, the pedicel very short, much shorter than the first funicle joint; funicle joints each distinctly narrowed towards distal end and furnished with partial whorls of long, diverging hairs as in illustration. The hairs on scutellum are not in a tuft as in female sex. Pronotum, mesoscutum, axillæ, and scutellum distinctly reticulated.

General color a dark brown, the legs lighter in part. Antennae with scape pale, the margins slightly embrowned the pedicel distinctly dark, and the flagellum uniformly light brown. Wings hyaline without markings.

Length, 1–1.08 mm.

Described from a series of balsam-mounted specimens, twelve females and two males May 28-31, 1925, one female and one male June 6, 1925, and two females and three males July 10, 1925; all reared by the writer from *Pulvinaria iceryi* during severe outbreak of this scale on sugar cane at Arecibo. It seems certain that this

is a hyperparasite on the primary parasite of this scale, *Aphycus flavus*, with which it was always reared.

Types deposited in U. S. National Museum; paratype material in collections of the writer, P. H. Timberlake, and the Porto Rican Insular Experiment Station.

The adult of the following parasite is very active and carries its abdomen at an elevated angle, a mannerism which is very characteristic of this species.

Aneristus ceroplastæ How.

This species, the only American representative of the genus, was first described in 1895 from two female specimens reared by T. D.

FIG. 4.—*Cheiloneurus pulvinaria* n. sp. **Above, antenna of male. Below, antenna of female. Much enlarged.** (Dozier)

A. Cockerell from *Ceroplastes* sp. on *Euphorbia hypericifolia* from Jamaica. Again in the same year Dr. Howard described *Coccophagus orientalis* from thirteen females reared by E. E. Green at Pundulaya, Ceylon, from *Ceroplastes actiniformis, Lecanium viridis, Lecanium coffeæ*, and *Dactylopius adonidum*, with the statement that it "seems to be an abundant and general scale insect parasite in Ceylon". According to Timberlake *Coccophagus orientalis* is a synonym of *Aneristus ceroplastæ*, and the species is widely distributed in the Tropics, occurring in Hawaii, Philippines, Java, India, and the West Indies. A female of this species was reared by the writer in New Orleans, La., from *Coccus hesperidum* material on citrus, January 15, 1925. The male has not yet been described and the writer deems it best to give here a full description of both sexes.

Female: Resembles greatly a *Coccophagus*, being distinguished from members of that genus only by the shape and structure of the posterior tibiae. Head slightly wider than long. Eyes rather large, with scattered microscopic hairs. Ocelli placed in an equilateral triangle. Lateral and hind margins of vertex with prominent black bristles, the dorsal surface with smaller black bristles scattered over the surface. Upper surface of vertex somewhat coarse, the cells being pentagonal or quadrate, but with each hind corner at eyes the pattern becomes longer and more transversely drawn out. Scrobes deep and about as wide and long at the antennal scape. Antennae with scape about equal in length to the pedicel and first two funicle joints, inserted just above the mouth and reaching to middle of the face, somewhat flattened from the side, under high power large and coarsely reticulated; pedicel short, triangular, slightly longer than wide, distinctly and coarsely reticulated. The entire flagellum very much flattened with the longitudinal elevations very strong and numerous. First funicle joint twice as long as pedicel, somewhat longer than broad, slightly longer than the second; the second and third funicle joints each successively shorter but of about the same width; joints of funicle supplied with numerous stout bristles. Club distinctly three jointed, with the first joint a little broader than the funicle joints, the second and third successively diminishing in width, all joints subequal in length, the last tapering to a blunt point. Thorax shagreened and rather densely set with stout black bristles, under high power with distinct and coarse reticulated pattern on dorsum with exception of the propodeum. Forewings nearly two and a half times as long as broad, the surface set with bristles which are much stronger and more prominent on the clouded area; marginal vein very long and straight, the stigma very short. Legs with the hind femora very large and flattened, the hind tibiae also much flattened with a distinct row of short stiff bristles along outer margin; middle tibial spur about as long as the first tarsal joint, which is decidedly longer than the first two tarsal joints combined.

General color is black with slight purplish reflections. Antennae dark brown with exception of the light colored scape. Wings hyaline, the forewings with a large discal fuscous blotch that extends completely across width of the wing. Legs blackish-brown, the tarsi and tibiae of front legs whitish; posterior half of middle tibiae also whitish.

Length, exclusive of ovipositor, 0.940–1.20 mm.

The male differs from the female in having the forewings entirely hyaline and the antenae pale in color; otherwise about the same as female in structure and coloration.

Length 0.7–.760 mm.

The writer has reared this species from *Ceroplastes cirripediformis* material on *Ficus*, June 28, 1925, at Santurce; from same

scale on Passion flower vine at Bayamón, July 3, 1925; from *Saisettia haemisphaeria* on avocado, June 16–18, 1925, at Río Piedras; from *Eucalymnatus tessellatus* on *Calophyllum antillarum*, June 21, 1925, at Santurce; and in large numbers from *Pulvinaria iceryi* on sugar cane at Arecibo. Of twenty-four specimens mounted, only five were males, showing a large preponderance of females, at least during those months. On July 10th many of the black pupae of this species were dissected out, the characteristic antennae making identification easy. They occurred only one to a scale, causing a characteristic blackened area to appear which easily distinguished the parasitized scales from the normal healthy ones.

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